The Dock and Harbour Authority

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Editorial Comments

Hydrographic Pioneering.

Hydrography, in its root sense, a description of the earth's waters, has come, in its later and more restricted application, to mean the contouring of the bed of the sea, which, especially in the neighbourhood of harbours, is a function of the greatest importance devolving upon port authorities, who must be responsible for and guarantee a safe approach channel to vessels seeking admittance to their precincts. Articles dealing with the subject have accordingly appeared from time to time in this Journal, attention being directed, in particular, to the modern method of echo-sounding which has so largely revolutionised the practice of marine surveyors.

Although soundings have been taken from the very beginning of navigation, it is only in recent times that the systematic charting of seas and channels has been pursued as an exact and reliable guide to the mariner. Nowadays, practically every maritime nation assumes responsibility for the charting of its coastal waters and those of its dependencies. The article by Mr. J. M. Lacey in the present issue describes the inception of such operations off the Coast of India.

In Great Britain, the Government first undertook this national duty a century-and-a-half ago by the formation in 1795 of a special hydrographic department of the Royal Navy, which, as stated in Mr. Lacey's article, was placed under the direction of Mr. Alexander Dalrymple, previously in the service of the East India Company. In 1808, he was superseded by Captain Thos. Hurd, R.N., and since that date the post has always been filled by an officer of the Royal Navy.

The Government hydrographic surveys, the results of which are published in the form of charts, issued under the authority of the Lords Commissioners of the Admiralty, are mainly concerned with coastal waters of broad extent, so that a number of harbour authorities find it necessary to supplement and amplify them with detailed local charts of river mouths and creek inlets, prepared by marine surveyors of their own establishments. Of the value of the information so placed at public disposal, there can be no question, and indeed, it is the sole means of securing safety of approach to a port by vessels incoming from the high seas. Further, the charts form a graphical basis for the adequate buoying and demarcation of navigable channels; it is an obvious corollary that in view of frequent changes in many places of the sea floor, charts must be kept well up-to-date if they are to be of reliable service.

Dundee Graving Dock Accommodation.

As reported elsewhere in this issue, a movement is on foot for the construction of an additional and larger graving dock at the Port of Dundee. At a recent meeting of the Harbour Trust the matter was discussed in connection with a notice of motion by Mr. Henry Main, a member of the Harbour Board, who had already publicly claimed that a considerable amount of work was lost to the City generally, by the lack of adequate dry dock accommodation. His contention was that vessels which came to the port as a final point of discharge afterwards had to go to London and elsewhere, including Rotterdam, for the execution of dry dock repairs, with the consequence that there was a loss of work to the United Kingdom in the reconditioning and survey repairs to such vessels.

The Port of Dundee possesses, at the present time, two graving docks, the larger of which has 500 feet length of floor, 49 feet entrance width and 15½ feet depth of water over sill at ordinary high water. The smaller is only 250 feet long, by 38 feet wide, with 13¾ feet of water over sill. There is also a Patent Slip, of which the cradle is 154 feet in length.

Our readers will recall that in a Report on the harbour and its accommodation, presented to the Trustees last year and published in this Journal in June, 1943, Mr. Norman Matheson, the Engineer to the Board, proposed the inclusion in a programme of future work of a dry dock on the site of the existing Fish Dock, with the following dimensions: Length to be such as to take a vessel 600 feet long; width of entrance to be not less than 80 feet; and the depth of water over sill at H.W.O.S.T. to be 25-30 feet.

That a new and larger dock would be an acquisition to the port can scarcely be doubted. The present accommodation is too restricted to meet the likely requirements of modern vessels. Apart from the question of cost, however, which has necessarily to be considered, there is the difficulty of deciding upon a suitable size. We have no information at present as to what may be in the minds of the Harbour Trustees, but clearly the dock must be commodious enough to take the largest vessel likely to present itself for entrance; while at the same time it will be recognised that any

Editorial Comments—continued

excess in dimensions represents, not only unnecessary capital expenditure, but also greater cost of operation and the possibility of inadequate user. Future enlargement to meet developments in ship construction must almost inevitably be ruled out of consideration. Graving docks have undoubtedly been lengthened, but widening and deepening are operations involving disproportionate and prohibitive outlay. This is the problem contronting the Trustees.

Commercial and Industrial Views on Waterborne Transport.

The commercial and industrial interests of Great Britain have just expressed their views on the British transport system through the medium of a report issued by a Joint Committee of the Association of British Chambers of Commerce and the Federation of British Industries. The report, which is concerned solely with merchandise and not with passenger traffic, covers a good deal of ground and in so far as it relates to road and rail transport, the matter is not germane to the purview of this Journal. But it comprises sections dealing with Ocean and Coastwise Shipping, with Canals and with Docks, upon which it is appropriate for us to make some comment.

It cannot be said that the very general terms in which the Report is couched afford much enlightenment on the attitude of the two bodies in regard to these branches of transport. The only definite statement of suggested action made in regard to coastwise shipping is that " this form of transport should have rates structures and conditions of carriage." The same desideratum is expressed in regard to canals, with the addition of a plea for " an improvement of facilities and, in particular, that the canal system should be brought up-to-date so that it can accommodate larger and more economical craft."

As regards Docks, the observations refer to the varied types of administration without any indication of preference and to the need for modernisation of service, without specific crtitcism of present methods. Monopolistic charges are stated to be a subject of concern to traders and it is urged—and in this we concur—that full publicity should be given to accounts and statistics with a clear indication, in the case of railway-owned ports, of the apportionment of charges over the various services, in accordance with the decisions of an appellate tribunal to be established for the purpose of dealing with complaints. Equality of port facilities is claimed for all forms of transport and restrictions by railway companies on traffic by road or other alternative means of transport are deprecated.

These are the only points in the report which affect port interests and it cannot be said that the criticisms on present practice are either numerous or severe. The recommendations made are certainly fair and reasonable.

The St. Lawrence Ship Channel.

In our last issue, arising out of a notice of the publication of a book on International River and Canal Transport, we discussed the subject of the internationalisation of inland waterways, instancing the European Commission of the Danube as an example of what had already been done in this direction. We specifically limited the field of illustration to the Continent of Europe although it may have been wondered why we did not go further and select what would appear to be the more prominent case of the Suez Canal. The reason was that although the Canal is a concern administered by a mixed directorate of several nationalities—French, English Egyptian and Italian to wit—the canal itself lies entirely within the territory of Egypt and the undertaking, as its name implies (the Suez Maritime Canal Company) is an enterprise run on purely commercial lines without any complications arising from divided sovereignty. An international waterway would naturally be one which flowed through the territory of more than one independent country and therefore under the jurisdiction of separate riparian powers. There is a case of this kind outside Europe to which we may perhaps direct attention in the present connection, since it is likely to play an important part in the near future as a means of opening out to overseas commerce a large region of productive capacity at present handicapped by a quasi-landlocked position.

Among the major projects of engineering enterprise held up until the conclusion of the present world-wide hostilities, none is of greater interest than that for the creation of a deep waterway, or ship channel, to connect the Great Lakes of North America with the North Atlantic. Water carriage is so universally recognised as the cheapest form of transportation that a scheme for developing a water route extending more than a thousand miles inland from the open sea to the heart of the North American Continent could not but be attractive to commercially-minded communities, nor has it failed to gain the enthusiastic support of shipping as well as trading interests. Manchester had set the example fifty years ago by creating an entirely artificial waterway, 35½ miles long and 28-ft. deep. The Texan port of Houston, taking advantage of a natural approach, has since provided itself with an improved dredged channel, 50 miles in length and 36-ft. deep. Amsterdam and other ports might be cited as having taken action on similar lines.

Accordingly, it is not surprising that public opinion in Canada and the United States should have concurred in the desirability of exploiting the natural channel of the St. Lawrence river to form a transportation link for the enormous grain harvests of Manitoba and Saskatchewan, as also the natural and manufactured products of Michigan and Ohio, to the outer world overseas. At present, the river is obstructed above Montreal by shallows and rapids which bar the passage of ocean-going ships. But these physical defects can be removed, and an International Joint Commission of the United States and Canada unanimously declared in favour of taking action to deal with them. In 1932, the two countries signed a treaty authorising the dredging of the waterway to a standard depth of 27-ft. and the St. Lawrence International Rapids Commission was established under the jurisdiction of the Federal Courts of both countries.

Opposition to the Treaty came, not surprisingly, from railway and canal interests in the United States, but no less emphatically from certain North Atlantic ports, which saw the adverse influence of a through route for shipping on the present one of interrupted stages with repeated handling of commodities. But such local interests could not be allowed to interfere with a project which would benefit so large a section of humanity. Various physical objections have also been raised to the execution of the project—such as the prevalence of ice in winter with the consequent closing of the St. Lawrence to navigation; unquestionably a serious handicap, but not a vital objection.

Then it has been asserted that the 27-ft. channel would be inadequate for vessels large enough to deal with the great volume of traffic. The permissible ship draught would be only 25-ft. On the other hand, the permissible draught through the present canals between Lake Ontario and Montreal is only 14-ft., yet, even with this limitation, the seagoing traffic of 1938 reached over 2½ million tons incoming and 5½ million tons outgoing. With a draught very nearly doubled such figures could be greatly increased.

Whatever reluctance to undertake the implementing of the treaty may be exhibited, it is bound to be over-ruled and the near future will see a great international shipping route opened to the centre of the United States and to the threshold of the Western Provinces of Canada.

Invasion Harbours.

The interesting series of works, described in this issue under the above heading, is a highly creditable record of what the British people are capable of achieving when necessity calls for resolute and enterprising action. There is, of course, nothing novel in the fundamental idea of employing floating caissons in the construction of harbour works. Such means have already been applied at Zeebrugge, Rotterdam, Dublin, Funchal and elsewhere with complete success. The particular merit of the military scheme lay in the co-ordinating of a comprehensive plan of great magnitude and its execution in the face of unprecedented difficulties, due not only to the restrictions imposed by war-time conditions, but to the exceptionally bad weather conditions. In spite of these difficulties, the operations were brought to a successful conclusion and so enabled the Allied forces to proceed with their campaign on European soil.

Early Hydrography in Indian Seas

An Account of Middle East Maritime Surveys in the Eighteenth and Nineteenth Centuries

By Lt.-Col. J. M. LACEY, M.Inst.C.E.*

The East India Company's Maritime Surveys

LAND surveying and the systematic mapping of India naturally followed the acquisition of territory by Lord Clive by means of British military power and it commenced with the conquest of Bengal after the battle of Plassy, but the British had already gained a starting base along the coast and connected waters; maritime surveys preceded land surveys by nearly two hundred years.

The East India Company was founded by Queen Elizabeth in December, 1600 and the hydro-cartography of the Indian Seas and coast line may be said to have begun when James Lancaster with a fleet of four ships and a victualler sailed from Torbay for the East on May 2nd, 1601. Lancaster and Middleton, the Commanders, however, only visited the " Eastern Islands." They reached Achen in Sumatra on June 5th, 1602, and returned home with a cargo of spice. From May, 1601 the East India Company set forth one or more voyages every year, and the Company's Sea Captains, exercised " great diligence in their astronomical observations, and in keeping careful journals, which contained valuable information in the shape of plotts and sailing directions." The information so obtained was condensed by John Davis of Limehouse into " Rules for our East India Navigation."

A department, for the systematic utilization of geographical knowledge, has been considered to be an important, and essential element in the Home Government of a great Colonial Empire. This principle was recognised by the Spanish Government ever since Colombus first sailed from Palos, when the " Royal Council of the Indies," for the Home Government of the vast trans-Atlantic possessions of Spain, was formed by Bishop Fonseca in 1524. " The Council of the Indies " contained the office of Cosmographer, whose duty was to furnish geographical knowledge to the Officers of State, and to supply instruments, and to lecture young pilots on navigation.

When the East India Company was first formed in London, its enlightened directors had not then a great empire to administer, like the " Council of the Indies " at Seville, but few days had elapsed before they saw the necessity for a geographical department, as part of their system of management. They were fully aware that correct geographical information was as necessary for a body of merchants, as for the administration of an empire, and in 1601 Sir Thomas Smith, the first Chairman of the Board of Directors of the East India Company, appointed Richard Hakluyt, the Archdeacon of Westminster, as Adviser and Historiographer for the Company, who thus became the founder of the East India Company's " Geographical Department."

Richard Hakluyt was of Welsh, not Dutch, extraction, educated at Westminster and Oxford, always keenly interested in matters pertaining to the Sea, while at Oxford he lectured on Geography, and on the improvement of maps. At the age of 30 he was acquainted personally with the noted mariners of Wapping. He was selected as Chaplain to Sir Edward Stafford, Ambassador at Paris (1583), and during his five years' stay there, under instructions from Secretary Walsingham, he collected information regarding Spanish and French movements. A prolific writer, his chief work was " The Principal Navigations, Voyages, Traffiques and Discoveries of the English Nation " in three volumes, 1598-1600. It was greatly enlarged and reconstructed in its second edition.

Edward Wright, mathematician and engineer, who accompanied the Earl of Cumberland on his voyage to the Azores, was added to the East India Company's Geographical Department in 1616, to carry out the necessary computations in connection with the construction of charts and maps, to collect the navigation details, and other information of geographical importance from the logs and memoirs of the voyagers of the Company. He was the first Englishman to publish the principles of Mercator's Projection in his book on " Corrections of Errors in Navigation."

Hakluyt died in 1616, and the Journals of the East India Voyages were handed over to the Rev. Samuel Purchase, the quaintest and a most entertaining old writer, but much too fond of taking liberties with his material. He published seven of his " Purchase, his Pilgrims."

To return to the mariners. In 1607 Captain Keeling, the commander of the third voyage, went to Surat, on the West Coast of India, at the mouth of the river Tapti, North of Bombay. He landed Mr. Finch to form a factory there, and sent Captain Hawkins to interview the Mogul Emperor Jahngir, then at Agra, and obtain his permission for the establishment, by the East India Company, of a factory at Surat; and an order to the Emperor's oofficers to " deal justly and favourably with the English." The Portuguese who had already established their settlements on the West Coast of India and on the Persian Gulf, endeavoured to drive the English from Surat, and from India, but were defeated at Swally, at the mouth of the Tapti. This action formed the beginning of British maritime supremacy in India. The result was the establishment of the factory at Surat, and around the Gulf of Cambay. In 1661 the island of Bombay was ceded to the English as the dowry of Catherine of Braganza, the bride of Charles the Second, who leased it to the East India Company for a nominal sum of money. Bombay eventually became the chief port on the West Coast of India.

The Eighteenth Century

From very early days armed vessels were employed by the East India Company at Bombay to protect the Company's ships from pirates that swarmed along the coast. About the beginning of the eighteenth century, the Bombay Marine was formed, under a Commodore, with a fleet of three " 20 gun " ships, and several armed Gallivats (1) and Grabs (2). In 1771 the Survey of the Coast of India was in its infancy. Captain John Ritchie surveyed the coast of the Bay of Bengal, and the outlets of the Ganges river. Captain John McCluer in the ships *Endeavour* and *Panther* surveyed the whole West coast of India from " Diu Head " to Cape Comorin, and made one of the earliest charts of the Bombay Harbour, and was the first to construct a chart of the Persian Gulf of any accuracy. Between 1777 and 1795 Lieutenant Archibald Blair surveyed part of the Andaman Islands (see Blair's *Survey of the Andamans*, Selections from the records of the Government of India Home 24). Port Blair in the Andaman is named after him.

Temporary Importance of Coringa

Coringa in 1787 was an important port on the East Coast of India, situated then at the mouth of the Godaveri river (Latitude 16°-59′ N.). It was sheltered from the south-west monsoon by a sand spit thrown out by the river, and also had the great security of a muddy bottom, and very good holding ground. So soft was the mud that vessels driven from their anchors would escape any serious damage, and could on the return of fair weather be warped off, and rendered sea-worthy without the necessity of going into dock. (Records of the Government of Madras: Harbours and Ports of the Northern Circars). Owing to the difficulty of navigation the Hoogly river on account of the dangerous " James and Mary Sands," the East India Company were seriously considering making Coringa the principal port on the East coast of India in place of

*Formerly of the Indian Public Works Department.

(1) Gallivat, a large 2-masted Malayo boat.

(2) Grab, a vessel containing 2 and 3 masts on the Malabar Coast.

Early Hydrography in Indian Seas—continued

Calcutta; and in 1790 Captain Michael Topping, who was acting as Astronomer at the Madras Observatory, was deputed to report on the possibility of Coringa being made the Company's chief port. (See "Selections" of the Government of Madras, 1855. Topping's memoir on Coringa). In a letter to Mr. Alexander Dalrymple, Hydrographer to the East India Company at this time, Captain Topping describes the great inundation of the Coast at Coringa, by a tidal wave which occurred on 26th May, 1787; and gives his deductions as to the causes which lead to this calamity. (See *Engineering*, October 8th, 1937, p. 407. Ocean Swells and Abnormal Tides).

Coringa is now far inland, and no longer a port, owing to the advance of the Godaveri river delta sea-wards. Hence for the decision of important problems in physical geography, and of some engineering problems, it is necessary to compare surveys of the same places made at long intervals.

Red Sea Navigation

The expedition to the coast of Egypt led to an examination of the Red Sea in 1799 and 1800, and Sir Home Popham, who commanded the fleet drew up "sailing direction" for its navigation. The Red Sea at that time was not absolutely unknown, as Lieutenant Court had taken the *Panther* as far as Suez, and a chart of the Red Sea had been drawn up by Lieutenant Robert White (both officers of the Bombay Marine) for which he received much praise from the directors of the East India Company.

Outer Harbour of Port of Aden

In 1803, Lord Valentia, when travelling in India, pointed out to the Marquis of Wellesley, Governor General of India at the time, that the Western Coast of the Red Sea was a perfect blank on our charts; and it was a national disgrace that it should be so. With the approval of the Governor General, the cruiser *Panther* of the Bombay Marine, under Captain Court, a man of high scientific attainments and an able seaman, together with the tender *Assaye*, under the command of Lieutenant Maxfield, were placed at Lord Valentia's disposal. Lord Valentia, and his party, sailed from Bombay on the 9th December, 1803, on a mission to the ruler of Tigre at Antolo. After landing at Massawa, and visiting Mocha, and other places along the coast, Lord Valentia eventually landed at Suez, at the end of January, 1806. Captain Court's chart of the Red Sea in two sheets is given in *Voyages and Travels in India, Ceylon, the Red Sea, and Egypt*, by George, Viscount Valentidela in 1802-06, published in three volumes in London, 1809.

Appointment of Surveyor General

In 1806 the hydrography of the Indian Seas was deemed of sufficient importance to warrant the appointment of a "Surveyor General" at Calcutta, and Captain Court was appointed to the post which he held until 1823. During this period 1806-1820 Captain Daniel Ross, with the assistance of Lieutenant Mayban and other officers of the Bombay Marine, were engaged in surveying the coast of China, the Straits of Malacca, a portion of the Gulf of Pichili, and of the Canton provinces, as well as some of the "Eastern Islands." Admiral Collison, R.N., at a later period, when surveying the China Seas, bears testimony to the accuracy of the work of the Bombay Marine.

To return to the Company's Geographical Department, in 1779 we find Mr. Alexander Dalrymple appointed as Hydrographer to the Department. Dalrymple came out to India, to Madras, as a Writer in 1759, he was sent on a voyage to the Eastern Islands and acquired much nautical experience. He returned to England in 1765, and was again out at Madras as a Member of Council in 1776, when Lord Piggot was Governor, and finally left India in 1777. In 1779 he was appointed Hydrographer to the East India Company. Dalrymple was a most indefatigable collector of geographic knowledge. He had little early education, but was a most industrious and untiring workman, and produced the *Oriental Repository* in two volumes. In 1795 the office of Hydrographer to the Admiralty was created and Dalrymple was appointed to the post, in addition to his post under the East India Company until 1808, when he was called upon by Lord Mulgrave to resign his office in the Company's services; he declined to do so and was dismissed on 28th May, 1808. It broke the old man's heart and he died on the 19th June of the same year, aged 71 years. Captain Hard succeeded him at the Admiralty. Some years later Captain Horsburg, F.R.S., was appointed Hydrographer to the East India Company, with Sir Clarke Wilkins as the librarian in charge of the original maps, memoirs and other records, on 10th November, 1810.

James Horsburg, born in the village of Elie on the South-east coast of Fife, began life as a cook and cabin boy, and rose to command the East Indiaman *Anna*. He sailed from England in 1802 and returned in 1805. In a paper printed in Philosophical Transactions, he detailed his meteorological observations, and was made a Fellow of the Royal Society in 1806. After years of indefatigable research he published his *East India Directory* in 1808, for which he received 100 guineas from the East India Company.

To return to India, Captain Court, Maritime Surveyor General, died in 1823 and was succeeded by Captain Daniel Ross (who surveyed the coast of China, and coasts in the Far East). Ross was called the "Father of Indian Surveys," and was the first "Surveyor General" to introduce regard for scientific accuracy in his surveys (see *Progress of Maritime Surveys*, Journal of the Asiatic Society of Bengal, vol. i. p. 327).

Persian Gulf Survey

In 1820 the survey of the Persian Gulf was commenced, the staff selected were all officers of scientific and literary attainments, viz. Lieutenants Haines, Kemp-thorn, Cogan, Pinching, Etherley, Whitlock and Lynch. Captain Bucks, the chief of the party, not a scientific surveyor, but a good sailor, with 16 years' service in the Bombay Marine, compiled the "Sailing Directions" for the navigation of the Persian Gulf. In addition to the survey which occupied ten years, Kemp-thorn contributed notes, on the identification of places touched by Nearchus; on the ancient commerce of the Gulf; and a visit to the ruins of Tahiri, which he identified with the missing old Mohammedan city of Siraf (see Royal Geographical Society's Journal V, p. 263). Whitlock contributed three papers, one a description of the island at the entrance to the Gulf; a second an account of the Arabs on the pirate coast, and the third a narrative of a journey to Oman (see Royal Geographical Society's Journal VIII, p. 170). This original survey of the Gulf reflects great credit on those who carried it out, when the imperfections of their instruments, the difficulties encountered and overcome, the suppression of piracy; hostilities of the Arabs; the fearful climate; and the great amount of work done are considered. Buck and several junior officers were invalided. In connection with the surveying instruments available, it may be pointed out that measurements were taken on shore by running a 10 foot rod along a chord between extreme points, and when work on shore was impracticable, recourse was had to measurement by sound. The vessels were anchored when the weather was calm, and the time was taken between the flash

Early Hydrography in Indian Seas—continued

and report of a gun, on the assumption that sound travels at 1,140 feet a second. All angles were taken by a sextant. The stations arrived at by triangulation were after verified by astronomical observations.

In 1832, the Bombay Marine was converted into the " Indian Navy " by the wish and the command of His Majesty King William IV, and Sir Charles Malcolm, the brother of Sir John Malcolm, then Governor of Bombay, was appointed Commander-in-Chief of the Navy. Sir Charles was born in 1782; entered the Royal Navy, and saw much service; was knighted by the Marquis of Wellesley in 1821; and became Rear-Admiral in 1827.

Under Sir Charles Malcolm's administration, the Indian Navy saw its most palmy days. An able administrator, and an enlightened patron of science and literature. Shortly after his arrival at Bombay he founded the Bombay Geographical Society, and was its President from its foundation until he retired and left India in 1838.

Perim Island, at entrance to Red Sea

Red Sea Survey

The first important act of Sir Charles' administration was the formation of the Red Sea Survey. At that time the ' over land ' route to India, via the isthmus of Suez, was under consideration, resulting eventually in Lieutenant Waghorn's Overland Mail Route to India in 1835. As a trial, coal was sent from Bombay to Suez in a collier, escorted by the 10-gun brig the *Thetis*, as a protection against the pirates that swarmed in the Red Sea. The collier was wrecked on the reef north of the Jaffatine Islands, and on return of the *Thetis* to Bombay, a complete survey of the Red Sea was resolved on.

The previous knowledge of the Red Sea was derived from the chart of 1796 by Lieutenant White; some sailing directions by Sir Home Popham; and Captain Court's charts of part of the western coast when with Lord Valentia.

Captain Moresby, a skilled surveyor, and seaman, was appointed to the *Palinurus* to survey the north half of the sea from Suez to Jeddah, and Captain Elwon in the *Benares*, the southern half from Jeddah to Bab-el-Mandeb. Here again the officers were chosen for their scientific and literary attainments. Carless, the future surveyor of the mouths of the river Indus; James Young; Pinching, who served in the original survey of the Persian Gulf; Powell; Barker, the Abyssinian traveller; Christopher, who fell at the Siege of Multan; Wellsted the author; and Felix Jones, then a very young officer, a skilled cartographer. No expense was spared in fitting out the expedition. All surveying appliances of the day provided; besides, ample supplies of well founded boats and tenders.

The sea was practically unknown and navigation dangerous; besides the oppressive climate to be endured, privations were great, and the pirates who swarmed at that time in the Red Sea had to be watched and contended against; but it was the fixed resolve of all the officers that " The Red Sea Survey " should be as perfect as skill could make it.

The first base was measured in 1830, and the survey continued steadily to its completion in 1834, by a system of triangulation down each shore. The work was frequently verified by measurement of bases, and almost daily astronomical observations on the shore of the sea, of the sun and the stars, and by differences of chronometer readings. The chart of the northern half of the Red Sea was published in two sheets in 1833, and the southern half, also in two sheets, in 1834, Two sheets of harbours in the Red Sea, and *Sailing Directions* by Captain Moresby and Elwon were published in 1841. The charts have served to guide thousands of steamers up and down one of the most important, at the same time the most intricate routes of the world.

The literature of the Red Sea is from the pens of Lieutenants Carless and Wellsted. Carless wrote a memoir on the Gulf of Akabah in 1833 (see Bombay Geographical Society Journal, vol. 1).

In the second volume of his *Travels in Arabia*, Wellsted gives an account of the survey operations in the Gulf of Suez and Akabah, and along this coast of Arabia (see *Travels in Arabia* by Lieutenant Wellsted, in two volumes, 1837). He also contributed notes on the changes along the coast of Arabia (Royal Geographical Society Journal V, p. 284) and *Observations on the Coast of Arabia between Ras-Mohammed and Jeddah* (Royal Geographical Society Journal VI, p. 51). Wellsted also published a book entitled *The City of the Caliphs* in two volumes, and a memoir on the *Island of Socotra* which he explored in 1837 (Royal Geographical Society Journal V. p. 129) and (Journal of the Asiatic Society of Bengal IV, p. 130). Wellsted died in 1843.

(*To be continued*)

Minister on Lessons of Bombay Dock Fire

The success of our Armies on the Continent and growing confidence in an early victory, resulted in a sharp increase in the number of fires in our Admiralty, Supply and Aircraft factories, said Mr. A. T. Lennox-Boyd (Parliamentary Secretary to the Ministry of Aircraft Production), when recently he presented trophies at the Supply Ministries' Industrial Fire Fighting Competitions at Manchester.

" This shows," he continued, " that there is still urgent need to do all that is possible to prevent fires which, as we know by recent events in India, may from very small beginnings lead to quite catastrophic results. You people in the fire-fighting services have equipped yourselves by hard training, to act instantaneously and efficiently. The reason why in Bombay many lives and immense treasure were lost was the lack of leadership and training. Nobody knew what to do, where to do it, and when to do it. What may have appeared at times to be unnecessary training in the course of your experience does enable you when emergency arises to know what to do and where to do it.

" I know something and you know a great deal from first-hand experience of the value of industrial fire fiighting. Since it began there has been a decrease in the number of fires in our industrial establishments."

North-East Coast Ports and Industrial Development.

British North-East Port Authorities have been invited to nominate representatives on the North-East Coast Industrial Development Association which has been formed as a result of a conference of local authorities, industrialists and others. The object of the Association will be to co-ordinate the efforts of local authorities and others concerned to secure post-war industrial prosperity in the area and to introduce, as far as possible, new industries and provide adequate employment for persons returning from war services. It also hopes to give the Government any support required and information necessary to bring this about. The Association will operate through a representative council and its business will be carried on by an executive committee. The conference was called by Lord Ridley, who will maintain a close interest in the Association.

Notable Port Personalities

XLVI—Mr. R. Hugh Roberts

Mr. Reginald Hugh Roberts has been Regional Port Director for the Bristol Channel Area under the Ministry of Transport since 1941 and for the South-western area since 1943.

Born in January, 1883, the son of the late Hugh Stewart Roberts, he was educated at King Edward's School, Birmingham, and at Birmingham University.

Mr. R. HUGH ROBERTS.

Adopting a business career, ultimately he became chairman of a number of trading concerns, including Fisher & Ludlow, Ltd., Super Oil Seals, Ltd., Edwin Showell & Sons, Ltd., and the Birmingham Guild, Ltd.

He is a member of the following public bodies: the West Midlands Advisory Council for further education; and the Grand Council, Federation of British Industries; and he has been on the Board of Trade Advisory Committee 1933-36; the Council of Art and Industry, 1935-7, sub-committee of the Production Executive Industrial Capacity Committee, 1939, and Lord Justice Scott's Committee, Ministry of Works and Planning on the utilisation of land and dispersal of Industry, 1942. He acted as Industrial Adviser to H.M. Commissioner for Special Areas, 1937-39, and as Deputy Director-General of Equipment and Stores, Ministry of Supply, 1939.

Mr. Roberts has published various memoranda on industrial conditions in America and Canada; Finance for Small Units of Industry; and Industrial Administration.

British Nautical Instrument Trade Association.

At the 26th Annual General Meeting of the British Nautical Instrument Trade Association held at Carlisle on 20th September, Mr. Albert Cater was elected President for 1945, and Mr. Francis Hughes, Vice-President. Messrs. Biggart, Lumsden & Co., of Glasgow, were re-elected as secretaries. During the year a new constitution was adopted by the Association. The Executive Committee will henceforth be known as the Executive Council, and will consist of six members: three from the distributors or nautical opticians, and three manufacturers' representatives.

The Port of Dundee

Proposal for New Large Graving Dock

At the latest meeting of the Dundee Harbour Trustees a proposal was put forward for the construction of an additional graving dock at the port.

The Clerk (Mr. A. R. Young) read the following notice of motion by **Mr. Henry Main:—**

"That the general manager and engineer of the harbour be instructed to prepare preliminary plans and approximate estimates for the construction of a new dry dock at Dundee on the lines suggested in his report on the present condition and future works at Dundee Harbour, dated March 2nd, 1943.

"That these preliminary plans and approximate estimates be submitted to and considered by the Harbour Trustees, prior to the whole matter being submitted to the Ministry of War Transport or other appropriate Government Department, together with a request that the Government will see their way to authorise a new dry dock at Dundee and award a substantial grant towards the capital cost thereof, and also that the Town Council of Dundee be invited to support the application of the Trustees for the award of the grant."

Speaking in support of his motion, Mr. Main said they had before the country to-day two White Papers which had the intention of looking after the well-being of the people of this country. He suggested that as the Government was taking such an interest in their well-being, it was up to them as citizens of the city of Dundee, and in particular as trustees of the harbour, to see that during their working lives sufficient employment was available for them.

Much had been suggested regarding the finding of new industries for the city, but he thought everyone was agreed that the old industries of the city deserved a little encouragement. Here was an industry to which no one could have any possible objection, either at home or abroad.

One of the birthrights of this country was the sea. They required ships to bring merchandise here, and these vessels require to be maintained. Unfortunately, during the past 50 or 60 years the dry docks of the country in many parts had been allowed to fall into a state of decay, or at any rate they had got very much out of date. It was well known that British shipowners whose vessels required accommodation for dry dock facilities had to send their ships to the Far East and the Continent.

Regarding the economic possibilities of the dry dock, he believed they could put such a strong argument to the Government, which was apparently willing to look after the welfare of everyone, to see that the old shipbuilding industry of Dundee was revived to its greatest possible extent. He believed that with the many friends they had in the shipping industry they could secure a dry dock that could be built and maintained economically. This was the time when they should be up and doing. He believed that with the co-operation of the Harbour Trustees and the large influence of the Town Council they could put forward to the Government a very suitable case. Whether the department he had mentioned in his motion was the correct one he could not say. They might have to go to the Board of Trade. At any rate, it was up to them to pursue this with all vigour and try to obtain a large grant from the Government to make such a dry dock for the city possible.

Mr. D. M. Christie, in seconding the motion, said that many years ago he called the attention of the Board to the appalling condition of the present dry dock. There were various reasons why they should go on with the scheme—and that forthwith. They wanted to establish their priority to carry on for the simple reason that many local authorities would be putting forward certain schemes for their own domestic purposes. Furthermore, they had the moral obligation of absorbing unemployment in the immediate post-war years.

Mr. Main's motion was supported unanimously, and it was agreed that Mr. Matheson's preliminary plans and approximate estimates be submitted to the Harbour Development Committee.

Notes of the Month

South African Port Dues.

The Railways and Harbours Administration of the Union of South Africa have, as from October 1st, increased harbour dues and charges at Union and South-west African ports by 10 per cent. as a special war surcharge.

Lloyd's Register and British Corporation.

Lloyd's Register of Shipping and the British Corporation Register of Shipping and Aircraft have decided to set up a joint committee to examine the possibilities of uniting the two Classification Societies with the object of providing more effectively the best possible services to shipping in the immediate future.

Grand Union Canal Company.

The Grand Union Canal Company announce that an extensive dredging programme has just been completed at the Regent's Canal Dock where there is now an over-all depth of 20-ft. below Trinity High Water when the depth on the outer ship lock sill is 24-ft.

Death of Swedish Port Manager.

The death took place on July 27th last of Mr. Erik Nyström, manager of the Port of Stockholm, a position which he had occupied since the beginning of 1943. Mr. Nyström, who was only 52, had previously held secretarial appointments in connection with the Stockholm City Council and the Gefle Town Council.

Dredging Operations at Spanish Port.

The entrance channel of the Port of Burriana, on the West Coast of Spain, slightly north of Valencia, has lately been silting up and a bank has formed across the fairway. Authorisation has now been given for dredging operations, which were begun last year, to be resumed. It is anticipated that with new and improved plant, the obstruction will speedily be cleared.

Greymouth Harbour Improvements.

The Harbour Board of Greymouth, New Zealand, have decided to apply to the Local Government Loans Board for permission to raise a loan of £100,000 in order to carry out certain improvement works. There is an important coal and timber export from the locality. Mr. W. C. Newnham, engineer-in-chief of the Works Department, recently inspected the port and made a report to the Government.

Proposed Re-opening of South African Harbour.

The harbour of Port Shepstone, Natal, has been out of use for some time on account of a sand bar which had formed across the river entrance. There is now an agitation among the local fishermen for the removal of the bar and the re-opening of the harbour. The South African Minister of Economic Development, Mr. S. F. Waterson has promised to look into the matter.

Appointment of New Dock Manager.

In succession to Mr. R. H. Jones, who is shortly retiring from the general managership of the Bristol docks, Bristol City Council have agreed on the recommendation of the Docks Committee to the appointment of Mr. F. D. Arney the present assistant general manager. Mr. Arney who is 45 years of age, entered the service of the Authority in 1914. In 1935, he was appointed assistant secretary and transferred to his present position in January, 1941.

Dock Workers' Hospital Commemoration.

Mr. John Weir, a member of the firm of R. & H. Green and Lilley Weir, Ltd., well-known in the Port of London in connection with the overhaul and repair of ships, is endeavouring to raise a Fund for the purpose of endowing a bed at St. Mary's Hospital for Women and Children, at Plaistow, London, E.13, of which he has been chairman since 1921, to " commemorate the splendid work of the dockers and stevedores of the Port of London throughout the whole progress of the war and home and abroad."

Distinction for Scottish Port Officer.

Captain George Elvin, assistant dockmaster at the Port of Leith, has received the M.B.E. for services rendered as Port Officer for the North-east Coast of Scotland since his appointment in August, 1939.

Port Development in Portugal.

An official decree has been published in Lisbon announcing the assignment of a sum of four and a half million pounds on the construction of new port works and the improvement of existing installations at ports in Portugal.

Death of American Port Official.

The death has been announced recently of Mr. C. L. White, Comptroller for the Vancouver Board of Harbour Commissioners. He had been known and respected in Canadian shipping circles for more than 20 years.

Mayoralty Nomination for Harbour Commissioner.

Alderman J. W. Mitchell, a member of the Tyne Improvement Commission, and of the Tyne Pilotage Board, has been nominated by the local Labour Party as Mayor of South Shields for next year.

Fire-fighting Appliance on the Tyne.

It is claimed that the new fire-fighting ship, *Northern Fire*, on the river Tyne is the largest and best equipped of its kind in Britain. Capable of pumping 20 tons of water a minute from the river to coastal areas ashore, it is also designed to cope with fires on vessels at sea. The vessel has been adapted from a French fishing vessel captured during the raid on Dieppe.

Merseyside Docks Access Committee.

Mr. Robert Letch, North-West Regional Port Director, Liverpool, has been appointed Cnairman of the Merseyside Docks Access Committee in succession to the late Sir William Chamberlain. Mr. A. H. Dodd, North-West Divisional Road Engineer, Manchester, has succeeded the late Lt.-Col. R. Howell Davies as a member of the Committee.

Wellington Harbour Accommodation and Facilities.

Following an official inspection of the water-front at the Port of Wellington, New Zealand, the following statement of port accommodation and facilities has been issued by the Harbour Board.

It states there are eight large wharves, with breastworks and sea walls aggregating three miles. Lineal berthing space is more than four miles with depths of water from 16 to 36-ft.

The city area of the water-front has 35 large stores with a working storage capacity of 55,000 tons. There are 44 overhead electric cranes of up to 5 tons capacity in the stores. To supplement ships' gear 77 hydraulic cranes, with lifting capacity of 2 to 20 tons, and 8 electric cranes with a capacity of 3 tons. Extra heavy lifts are met with the self-propelling crane; capacity 80 tons. The mobile fleet includes 43 tractors and 395 trailers.

The floating dock has a capacity of 17,000 tons, recently making a record lift for its 13 years of operation. The Aotea Quay breastwork, completed in 1940, is 3,680-ft. long with 36-ft. depth available at low tide for most of the length. Shed 49, on this quay has a capacity of 9,000 tons and is 650-ft. long and 113-ft. wide.

The new shed 33, built to replace that destroyed by fire last year, provides double the original accommodation. A new weighbridge, at the corner of Cable and Taranaki Streets, with a 20-ft. by 8-ft. platform, is nearing completion. The capacity is 20 tons.

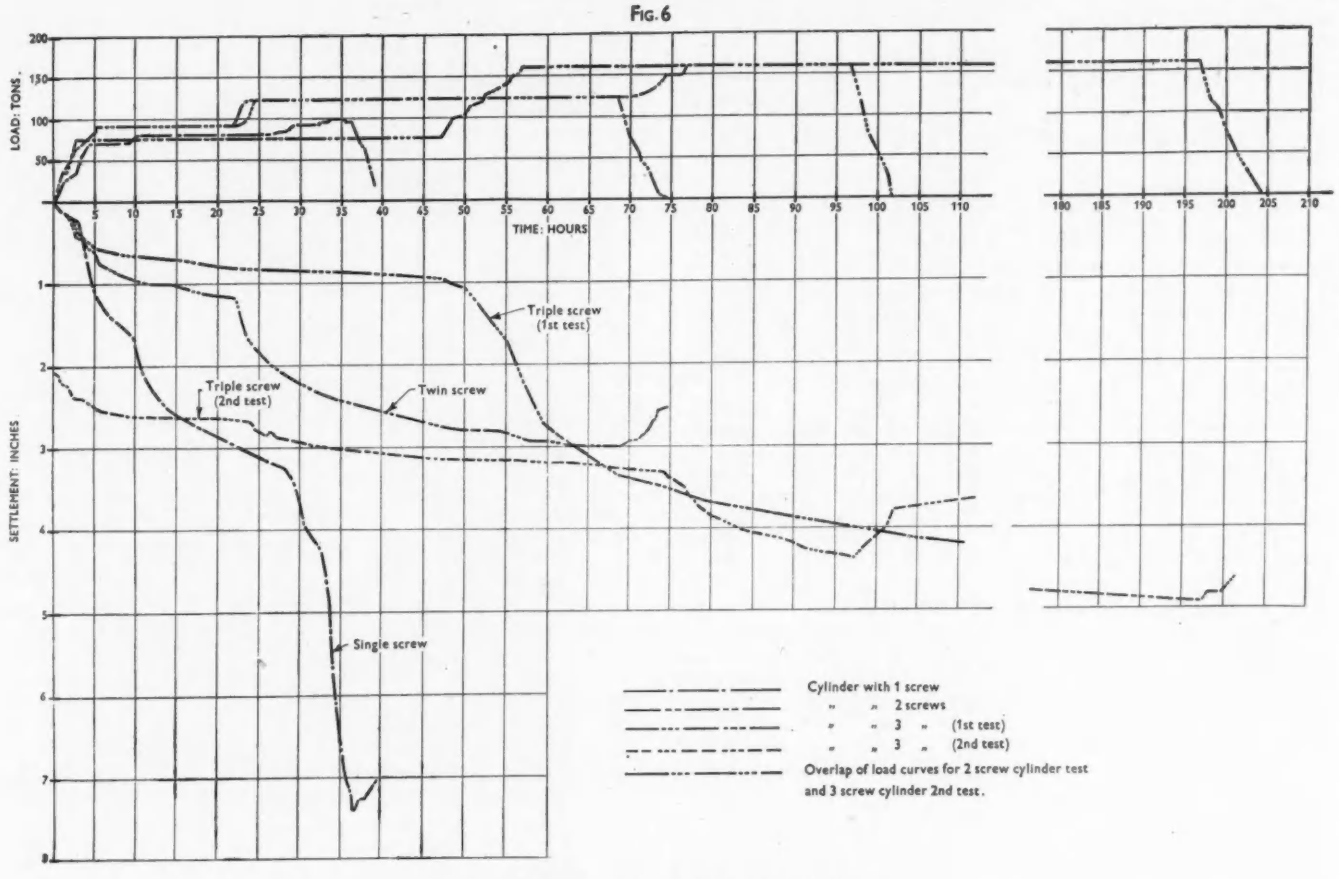
To overcome the smoke nuisance from the board's hydraulic pumping station, two electrically-driven pumping units have been ordered and are due to arrive soon. If satisfactory, a third will be purchased and the existing coal-fired steam boilers and pumps eliminated.

The Design of Wharves on Soft Ground*

By HORACE DENTON MORGAN, M.Sc. (Eng.), M.Inst.C.E.

(Concluded from page 136)

FIG. 6


LOAD: TONS.
TIME: HOURS
SETTLEMENT: INCHES
Triple screw (1st test)
Triple screw (2nd test)
Twin screw
Single screw
Cylinder with 1 screw
" " 2 screws
" " 3 " (1st test)
" " 3 " (2nd test)
Overlap of load curves for 2 screw cylinder test and 3 screw cylinder 2nd test.

TESTS ON SINGLE, TWIN AND TRIPLE SCREW CYLINDERS.

Screw Cylinders

It is interesting to recollect that in 1848 Brunel carried out some experiments for the foundations of a large railway bridge over the Wye at Chepstow. He prepared some cast-iron cylinders 3-ft. in diameter and 10-ft. long with a skin 1½-in. thick. A number of these were joined together and at the lower end a helical flange was fitted projecting 12-in. all round and with a 7-in. pitch. This first screw cylinder was driven 58-ft. through stiff clay and sand down to the marl without any great difficulty. However, when a second cylinder was screwed boulders were encountered, and there did not appear to be sufficient power to overcome these obstacles. Also in one instance the screw entered a bed of running sand and did not drive at all, the cylinder merely revolving without any downward movement. In this case the cylinder was raised and the helix extended, when the cylinder was successfully screwed. Brunel, however, was not satisfied that a foundation on these cylinders for such a large bridge would be successful, and he reverted to caissons 8-ft. in diameter and sunk under compressed air.

These experiments do not appear to have been followed up and little more was done for many years on the development of the screw cylinder. The improved technique in connection with screw piles was eventually applied to them, and screw cylinders came into use at first chiefly for bridge piers.

*Paper read before the Institution of Civil Engineers, January, 1944. Reproduced by permission.

The screws are usually of cast iron, the helical blades being carried on a cylindrical shell with an internal flange at its upper end machined and drilled to match the end of the cylinder, the connection being made by bolting. The screws are usually open at the lower end of the cylindrical body, the edge being serrated. The cylinders are of cast iron, 3-ft. in diameter and 9-ft. long, with an internal flange at each end. The flanges are machined to an accurate face, and when a number of sections are joined to form a complete cylinder they line up with remarkable accuracy.

In very soft ground it is possible to screw cylinders with the end closed, but in harder ground they are screwed with the end open and the material which enters is afterwards removed, usually by air lift. The cylinder is then filled with concrete.

The screws for these cylinders are usually 7 or 8-ft. in diameter. It was found that the use of a single helix for the blade resulted in an eccentric pull during screwing. Therefore the screws are designed with two blades symmetrically disposed, each blade making approximately a half turn. The pitch of the helix is usually 18-in., that is, 9-in. in each blade. In most ground the open-ended cylinder can be screwed without great difficulty, but occasionally it is necessary to make limited use of a water jet in order to penetrate hard zones.

The gear for screwing the cylinders is of two kinds, one being a larger and more powerful form of the capstan used for screw piles, which has already been described, and the other a screwing machine which runs on a track laid upon the structure already completed. This machine is intended to be capable of assembling

Design of Wharves on Soft Ground—continued

and screwing the cylinders. It is equipped with derricks and the driving ring is built into the structure. The rig is large enough to permit its extension forward beyond the bent of cylinders last screwed by a distance sufficient to enable the next bent to be pitched and screwed. It is a formidable structure and can impose on the cylinders a load of the same order as the full designed load of the wharf.

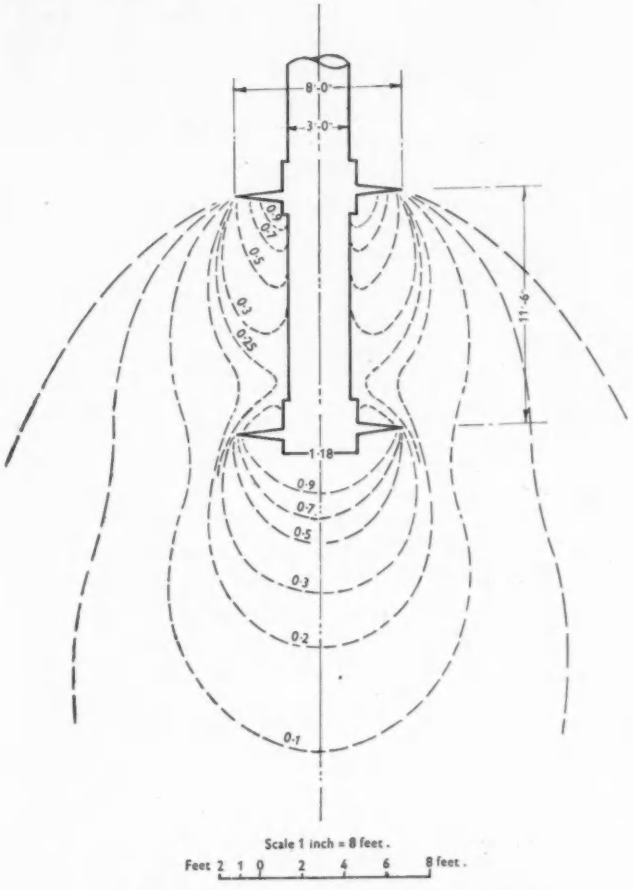


Fig. 7. Estimated Distribution of Vertical Stress.

The most recent development in the use of the screw cylinder for a deep-water wharf in very soft ground has been carried out during the war, and it is not permissible to refer to the site. The difficult conditions which existed are well illustrated by the fact that a test pile was driven to a penetration of 87-ft. and a total length of 120-ft. without any satisfactory set being obtained. The next step was to screw and test a 3-ft. diameter screw cylinder with a 7-ft. screw, the penetration being 27-ft. The test of this cylinder was not satisfactory settlement still continuing 20 hours after the load had been placed. Another cylinder, this time with an 8-ft. screw, was sunk to a penetration of 50-ft. and tested with a load of 100 tons. This also was not satisfactory; the settlement under load was more than 7-in., and a preliminary design of the wharf had indicated that the cylinders would be required to carry maximum loads of 123 tons in general, the cylinders in the second row from the cope being required to carry between 150 and 160 tons. The adoption of a larger screw was not practicable and, owing to the concentrated loading, closer spacing of the cylinders could only be adopted at the expense of a disproportionate increase in the quantity of material required. Therefore it was decided to test a cylinder having two screws, the upper being separated from the lower by a standard 9-ft. length of cast-iron cylinder and being cast with an additional flange in place of the serrated lower end. It was thought that the screwing of twin-screw cylinders would be within the capacity of the plant as the ground was of such a soft nature. In addition, the passage of the first screw would result in the alluvium being disturbed, so that the frictional resistance on the second screw would be reduced. It was believed that the separation of the two screws by an interval of 9-ft. would enable the ground immediately below the upper screw to carry a unit pressure comparable with that developed under the lower screw, provided that sufficient time were allowed for the ground disturbed by the passage of the lower screw and cylinder to re-consolidate. A twin-screw test cylinder having 8-ft. screws was sunk to a penetration of 57-ft. to the lower screw and a test load was applied.

The results of such tests are most clearly indicated by plotting the load and settlement simultaneously against time. Fig. 6 shows this method applied to the test cylinders under discussion. It will be seen that the single-screw cylinder was first loaded with 72 tons and that 5 hours after completion of the loading the settlement was 1.06-in. and was increasing fairly rapidly. An increase of load by a further 8 tons rapidly accelerated the sinkage, which had become more than 3-in. at 25 hours from commencement of the test. At this point the load was increased to 90 tons and finally to 100 tons. As soon as the load of 80 tons was exceeded the cylinder broke down completely and settlement took place rapidly, being 7-in. 35 hours after the commencement of the test; the load was then removed. The twin-screw cylinder was first loaded with 90 tons, the loading being competed in 5 hours. The cylinder sank 0.7-in. during this time and the load was left on for a further 17 hours, by which time the sinkage had become 1.2-in. The load was then increased to 123 tons. Further settlement took place under this load, but the rate diminished gradually and finally ceased at 62 hours from commencement of test, no movement being recorded for a further 7 hours. The load was then removed, and the cylinder recovered by about 1-in. This result was interesting, as the twin-screw cylinder under a load of 123 tons gave a rather better result than the single-screw cylinder under a load of 80 tons. The mean pressure imposed on the ground by the screws on this basis was 1.32 ton per square foot for the twin-screw cylinder and 1.59 ton per square foot for the single-screw.

A month later the twin-screw cylinder was re-tested, the initial load being 92 tons. The resulting settlement was only ½-in. and no increase took place for 15 hours. On increasing the load to 125 tons, further settlement took place very slowly, reaching 1¼-in. in 45 hours. The load was then increased to 161 tons. This resulted in an increase in the rate of sinkage and the load was removed. It was clear that the maximum capacity of the cylinder had been reached at 125 tons. The ground disturbed by the passage of the screws had, however, been re-consolidating for only one month, and it was believed that this period was not sufficiently long. In addition, the total estimated load which the wharf cylinders would be required to carry was the aggregate of a number of individual loads assumed to occur simultaneously—a case that would happen very infrequently in practice and then only for brief periods. On this basis it was considered that the twin-screw cylinder might be considered satisfactory, as a further improvement in bearing capacity was expected after re-consolidation of the disturbed ground.

In order to deal with the heavier loading required for the cylinders in the second row, a cylinder with three screws was tested, and the result is shown in Fig. 6. The load was gradually increased as before and reached 163 tons in 57 hours, by which time the total settlement was 2-in. This load was left on for a further 140 hours, the settlement slowly increasing to nearly 5-in. At this point settlement was still taking place, but extremely slowly. The remarks made above as regards the frequency of incidence and time of duration of estimated maximum load applied in an even greater degree to the triple-screw cylinder, and it was considered satisfactory to adopt the latter for the more heavily-loaded cylinders in the second row. Under a load of 163 tons the mean pressure imposed upon the ground over the effective screw area was 1.19 ton per square foot.

The effect of re-consolidation of the disturbed ground was well shown by further tests carried out on cylinders which had been in position for about 10 months. A cylinder with three 8-ft. diameter screws loaded with 163 tons had a maximum settlement of only 1-in. and recovered ½-in. when the load was removed. A twin-

Design of Wharves on Soft Ground—continued

screw cylinder with 8-ft. diameter screws and loaded with 123 tons sank only ½-in., with a recovery of ¼-in., and a twin-screw cylinder with 7-ft. diameter screws under a load of 108 tons settled 0.4-in. and recovered by 0.15-in. These tests were considered very satisfactory as confirming the anticipated effect of re-consolidation.

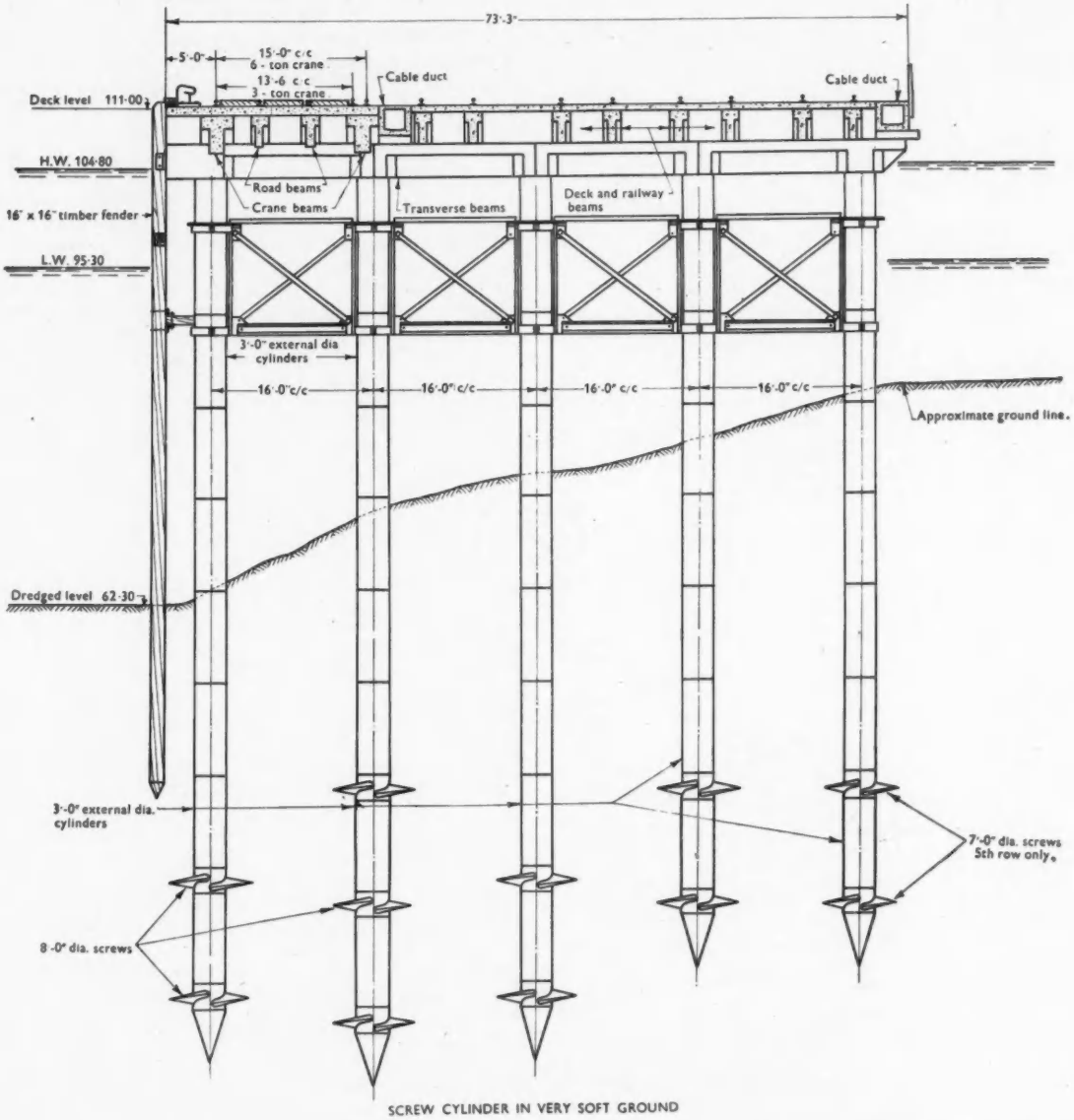
In giving the value of the unit pressures exerted by the screws on the ground, the effect of skin friction on the cylinder itself has been ignored. Immediately after screwing this is probably nil. After re-consolidation of the ground it may have some value, but is believed to contribute in a very minor degree to the improved performance of the cylinders after re-consolidation.

An estimate of the distribution of stress in the ground surrounding the screws on a basis of the " pressure-bulb " hypothesis is shown in Fig. 7 for the twin-screw cylinder. This hypothesis relates to the distribution of stress in an elastic, homogeneous, and isotropic medium, and is generally believed to give an approximate picture of the stressing of soil so long as the shear strength of the latter is not exceeded.

Some tentative attempts have been made to apply photo-elastic methods to the problem, using gelatine as a medium, and the results have been sufficiently encouraging to justify further work on a larger scale.

Unfortunately it was not possible to obtain undisturbed samples of silt for laboratory test at the levels to which the screws were driven. The nature of the silt is known to vary only slightly with the depth and some undisturbed samples have been taken from a little below bed-level. The results of tests on these are not available at the time of writing.

FIG. 8



SCREW CYLINDER IN VERY SOFT GROUND

Details of construction of the deep-water wharf are shown in the cross-section in Fig. 8. The cylinders were spaced 20-ft. apart centre to centre longitudinally.

In order to economise in steel a reinforced concrete design was adopted, and for a number of reasons it was laid down that precast units should be used, so that the work of making the beams could be carried out on shore. A standard design was adopted for the heavy transverse beam as well as for the longitudinal beams. The former was not continuous, and provision was thus made to accommodate the small movement resulting from any unequal initial settlement of the cylinders. The cylinders were screwed to a level 2-in. higher than the design level, in order to allow for

Design of Wharves on Soft Ground—continued

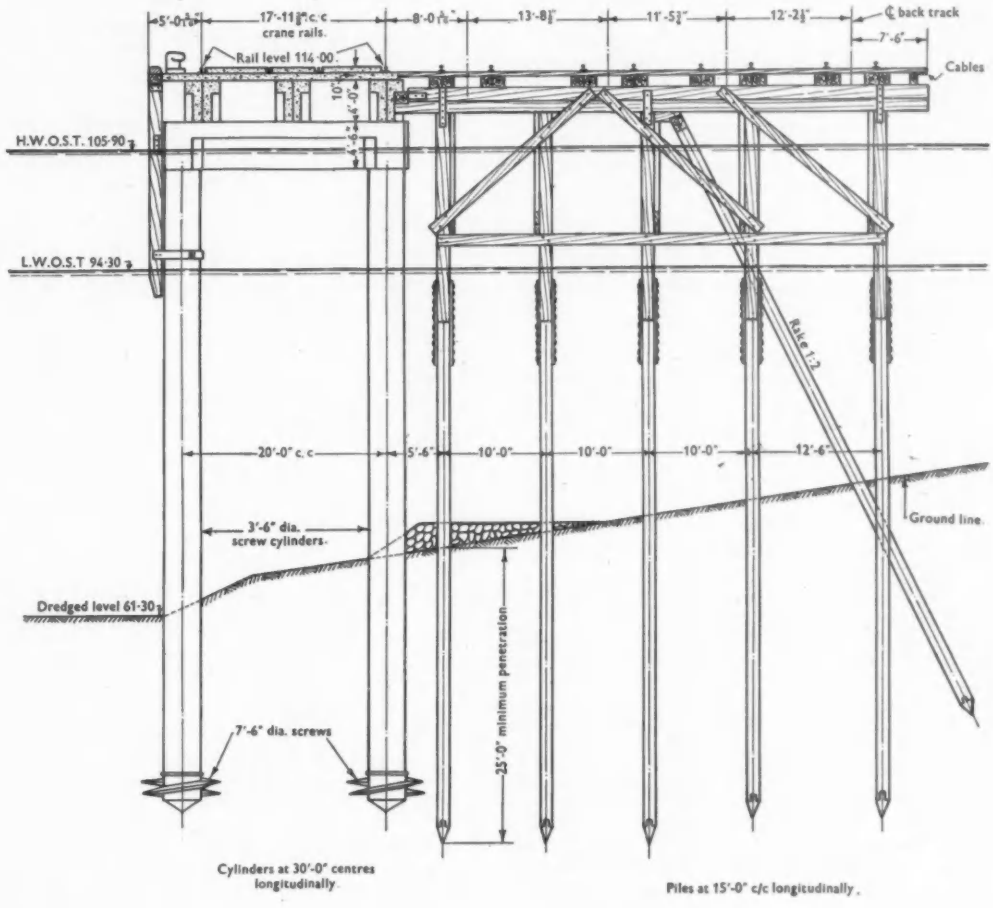
initial settlement, and the records show that the actual movement ranged from 1-in. to 1½-in. The longitudinal beams were of two types, one for crane and the other for railway loading. Steel bracing was applied above low-water level in the manner shown in the cross-section.

Another form of screw cylinder which is of interest consists of a screw similar to those already described. The cylinder, however, is of thin steel plate of about 12 gauge, with circumferential corrugations. This steel cylinder is made up in lengths of about 12-ft. and is intended to act as a form for a reinforced-concrete cylinder which is built up on the screw after it has been placed in position. In order to transmit the torque to the screw during driving a temporary mandrel is used inside the steel shell, which can be dismantled before the concreting is carried out. A usual diameter for this cylinder is 3-ft. 6-in. The reinforcement steel is built up by welding into cages which are lowered into the shell as a unit.

When using this system a difficult point arises as to whether the screw shall have an open end. The open end facilitates the screwing considerably, but it is obvious that unless material can be completely removed from the interior of the shell the concrete column will have no direct connection with the screw. On works in non-water-bearing ground, or in water-bearing ground in favourable circumstances, the complete removal of material from the cylinder can be ensured. For wharf works, however, this is generally not so, and it is preferable to use a screw with a closed end. Unless the ground is very soft, the torque and resistance to penetration are high, and it is usual to build water-jets into the nose so that water at high pressure can be used to facilitate the screwing. Cylinders with closed ends were first used for wharf works and were successfully screwed in the case of the Brooking Street wharf at Rangoon.[1] Water-pressure at 160 lbs. per square inch was applied whenever the torque became too great. Cylinders screwed at Rangoon in this manner carried a test load of 228 tons with a permanent settlement of about ½-in.

Fig. 9 shows an example of a deep-water wharf in which concrete cylinders with screws are used. The bearing capacity of the ground was fairly good and it was possible to use driven piles to carry the loading imposed by rail traffic. There was, however, heavy crane loading and it was also necessary to provide for very heavy loading from road vehicles at the front of the wharf between the crane tracks. For this reason reinforced concrete superstructure carried upon cylinders was adopted. The piled section was capable of quick construction and was used as a staging from which the cylinders were screwed. This avoided the necessity for working " over end," and the cylinders were spaced 30-ft. apart centre to centre longitudinally. In this case also, the reinforced concrete superstructure was carried out entirely in precast units. Owing to limitations in the capacity of the erection cranes it was necessary to cast each beam in two halves, which were bolted together when in position. In order that the two parts should match accurately one half was cast first and the second half was then cast against it back to back. In this manner any irregularities which occurred in forming the meeting face on the

FIG. 9



WHARF EMPLOYING CONCRETE CYLINDERS ON SCREWS.

[1] P. A. Scott, A.M.Inst.C.E., "Trial Screwcrete Cylinders for new Brooking Street Wharf," Journal of the Association of Engineers in Burma.

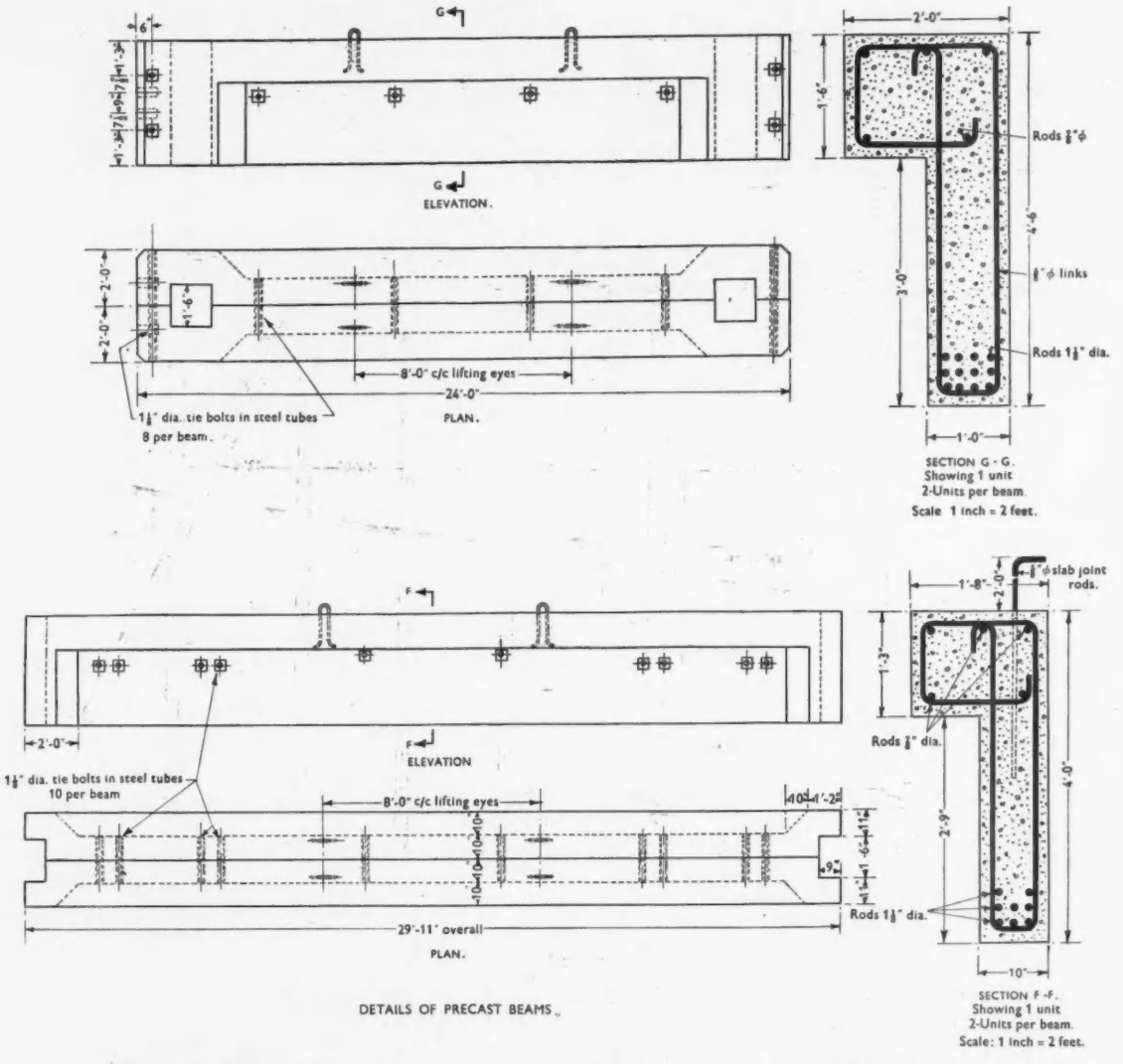
Design of Wharves on Soft Ground—continued

first half were repeated in reverse in the second, and the two matched accurately when finally erected. Typical beams of this type are shown in Fig. 10.

During construction a decision was taken to use larger cranes over a section of the wharf. In order to meet this new requirement the device shown in Fig. 11 was adopted. The two half-beams were placed in position with a gap between them. A shutter was applied at the bottom and the central part of the beam was then concreted, thus giving the whole unit the additional strength required.

" cage " of structural steelwork. This is bolted by clips to the bent of piles last screwed, and the piles which are about to be screwed are swung out by the crane and hung in similar clips on the other side of the cage which are capable of rapid dismantling and refitting. When these clips have been bolted up the crane lowers the pile on to the sea bed and is then used to place the electric capstan in position, the guy wires being pulled taut in the manner described above. As screwing progresses it is necessary to harden down the guys from time to time as they are slacked off by the descent of the electric capstan. The cages are usually of parallel

FIGS. 10



DETAILS OF PRECAST BEAMS.

Practical Problems

It may be of interest to describe briefly some practical problems which arose during the construction of screw pile and cylinder wharves.

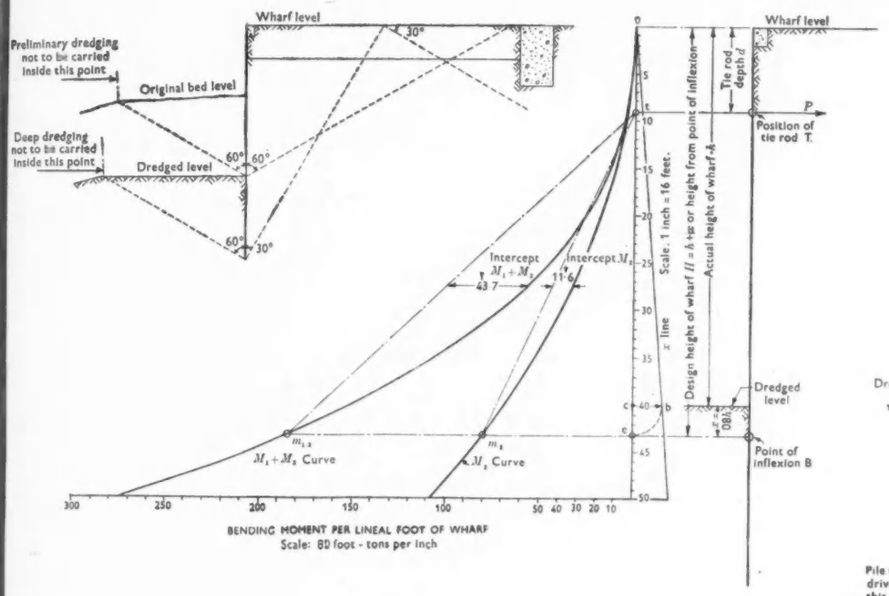
The construction of screw-piled wharfage is generally carried out " over end," that is to say, the erection cranes work from that part of the wharf which has just been constructed. The advantage of this system is that it avoids the use of temporary staging; but, on the other hand, there is the disadvantage that progress is slow unless arrangements can be made to place a temporary deck and track as quickly as possible upon the bent of piles last screwed. The Author has known a bent of four piles to be screwed in a day, so that it will be appreciated that rapid placing of the deck is an important consideration.

The screw piles are usually located accurately by means of a construction suitable for a straight run of wharf. Where bends are necessary radial bays are included and a special radial cage is used. A difficulty occasionally arises with the simple short-nosed screw when the sea bed is not level—possibly it may have been already dredged to a slope. In these circumstances at the actual moment of commencing to screw the pile there is a tendency for the screw to walk along the sea bed owing to its periphery bearing on the ground at one side only. This difficulty has sometimes been dealt with by employing a long-pointed nose, but in the Author's experience the most effective method, when the necessary plant is available, is to take out one or two grab-loads of ground and make a small pocket in which to start the screw.

Another matter which requires supervision is the placing of the forward anchor for the capstan guy wire. A strong and quite understandable reluctance exists to taking time to move the anchor

(a)

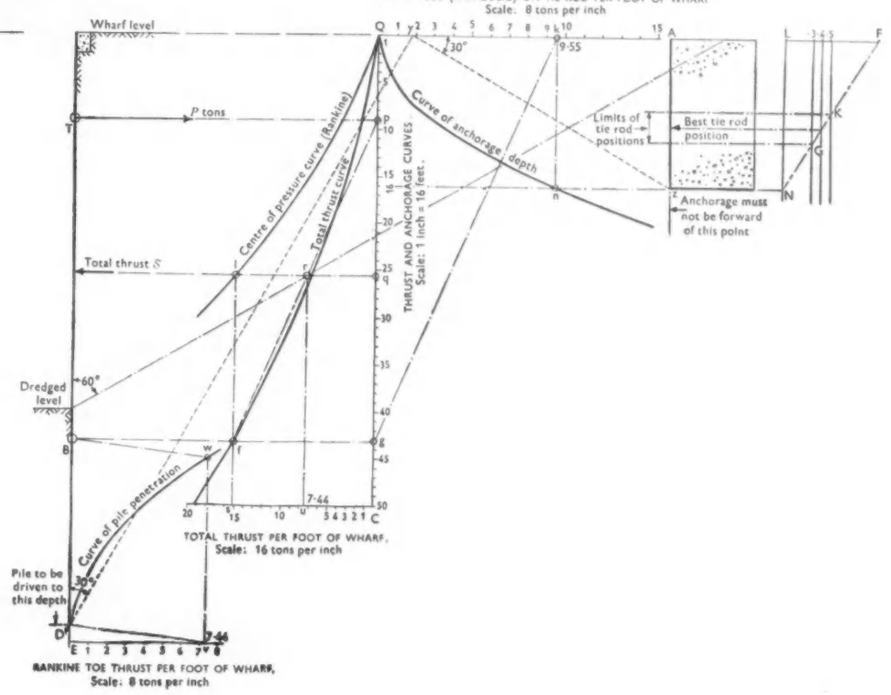
FIGS. 12



BENDING MOMENT PER LINEAL FOOT OF WHARF
Scale: 80 foot - tons per inch

(b)

DESIGN PULL (PARABOLIC) ON TIE ROD PER FOOT OF WHARF
Scale: 8 tons per inch



DESIGN CURVES FOR SHEET PILED WALLS WITH ONE TIE ROD.

Design of Wharves on Soft Ground—continued

fairly frequently and it sometimes happens that this operation is postponed longer than it ought to be. The result is that the two parts of the guy wire make markedly dissimilar angles with the vertical. A common belief is that since the wire passes through fairleads in the capstan the pull on the two sides must be equal. It will be appreciated, however, that the horizontal components on the capstan may be substantially out of balance owing to the dissimilar angles of the guys, and this may result in sudden bending of the pile-bar. The ready way in which a solid bar 8-in. in diameter will bend is surprising to anyone who has not witnessed it. In soft ground the screwing of the pile is a simple matter. Occasionally, however, in alluvial ground lenses of sand occur, and these may cause trouble. Sometimes boulders are encountered, resulting in tripping of the overload switches on the motors. These obstacles can frequently be passed by reversing the motors, screwing the pile back a little, and then again screwing on. When using a screw which has been proportioned for use in a soft alluvium it is sometimes difficult to pass a hard lens of sand. In stubborn cases of this type, water-jetting adjacent to the screw is an effective remedy, but it must be used with caution.

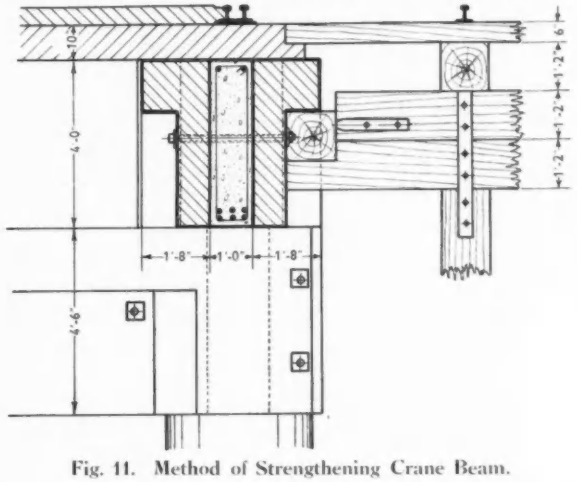


Fig. 11. Method of Strengthening Crane Beam.

Screw piles are usually put down to an exact level and cutting off at the head is thus avoided. The only exception to this rule arises when harder ground is found a little above the designed level for the screw. In such cases the screw is sometimes stopped in the harder ground instead of being screwed right through into weaker material. In the great majority of cases, however, the screws go to their designed level. A little experience of site conditions indicates the allowance to be made for over-run after shutting off the motors, and it is often possible to screw a large number of piles to their design level plus or minus 1/16-in.

Other methods of building wharves on soft foundations are sometimes adopted by Continental engineers. For example, large areas of alluvium may be dredged and the space filled with good sand upon which caissons are sunk to form a wharf wall.

Sheet-Pile Wharves

During the war it has been necessary to design and construct wharves for lighters and ocean-going vessels at high speed and with the minimum of material, at sites which consisted almost entirely of sand. The latter can hardly be described as constituting a soft foundation, but it is believed that the methods employed in the design overlap the subject of this Paper and justify its inclusion.

It was apparent that in order to meet the requirements as regards the time allowed for completion a form of construction consisting of sheet-piling tied back to anchors would be most suitable. This type of wharf does not present much difficulty in design in the case of berths for shallow-draught vessels, but where depths are required sufficient to accommodate ocean-going shipping the bending moments imposed upon the sheet-piling become rather large and the difficulties of design increase rapidly with the depth.

In almost every case the site needed to be dredged in order to obtain the requisite depth of water, and advantage was taken of this in the design, since the sheet-piling could be driven, the anchors and ties placed in position, and the filling at the back of the sheet-piling placed before the dredging was completed to the face of the wharf. Terzaghi and Stroyer have shown that in such circumstances the distribution of pressure on flexible walls is not linear, but parabolic, the result being a reduction in the maximum bending moment induced in the flexible wall and an increase in the tie-rod pull.

It was known that some adjustment in the wharf-level and the dredged level were likely to be made at each site and that communication with the Resident Engineer would be difficult. An attempt was therefore made to prepare design diagrams for his use to enable him to adjust the design of the structure to conform with varying conditions. These diagrams are shown in Fig. 12.

The following notes on the diagrams give details of the manner in which they are to be used. It is assumed that the depth or dredged level below wharf-level has been determined as well as the depth of tie-rod below wharf-level. The latter is usually dependent upon low-water level:—

(a) **Bending Moment on Sheet Piles.**—1. Select tie-rod of depth d and dredged level depth h, both measured from the cope. (Tie-rod level should as near low-water-level as practicable).

2. Set these down on depth scale obtaining points t and c respectively. Draw cb cutting the x line in b: cb represents depth of point of inflexion B below dredged level.

Make ce to cb and draw horizontal line Be through point of inflexion, cutting bending-moment curves M_2 and (M_1+M_3) in points m_2 and $m_{1,3}$ respectively. Join m_2t and $m_{1,3}t$: m_2tO and m_1m_3tO are bending-moment diagrams for sheet-piling. The horizontal intercept between $m_{1,3}t$ or m_2t and the appropriate curve gives the bending-moment values at any required depth. Curve M_2 gives bending moment due to head of water in filling. Curve (M_1+M_3) gives bending moment due to earth-pressure and surcharge added together. The (M_1+M_3) value is subject to a reduction-factor of 0.6.

3. Find maximum intercepts and add 0.6 (M_1+M_3) to M_2, giving the bending moment in the sheet-piling, in foot-tons per linear foot of wharf.

(b). Tie-Rod and Pile Penetration; Depth and Position of Anchor.—1. Draw horizontal line at tie-rod depth, cutting depth-scale in p.

2. Draw horizontal line through B, cutting total thrust curve and depth-scale in f and g respectively.

3. Join f to p and make gk parallel to fp, cutting scale of tie-rod pull in k. Qk represents the pull in the tie-rod, in tons per linear foot of wharf.

4. Draw the vertical kn through k, cutting the curve of anchorage depth in n; kn represents minimum depth of anchor required. Draw horizontal through n, cutting fixed vertical LN in N.

5. Draw the vertical from f cutting centre of pressure-curve in I and thrust scale in s. Cs represents total thrust in tons per linear foot of wharf.

6. Draw horizontal lrq cutting fp in r and depth scale in q.

7. Draw vertical through r, cutting thrust scale in u. Cu represents thrust at the toe of piling in tons per linear foot of wharf.

8. Set out Ev one toe-thrust scale (note scale doubled so that Ev=twice Cu).

9. Draw vertical vw, cutting the curve of penetration in w.

10. Join wB and make vD parallel to wB, cutting the pile at D. D gives minimum penetration required.

11. Draw Dy at 30 degrees to vertical, cutting cope-level in y.

12. Draw yz at 30 degrees to horizontal, cutting horizontal through n in z. Az represents face of anchor in position and depth. Join NF, cutting proportional verticals in G and K.

13. Horizontals through G and K give the limits of level between which the tie-rods should be placed at the anchor end.

Basis of Design:

Weight of filling, 110 lbs. per cu. ft.; Angle of repose ϕ, 30 degrees; Surcharge, 4 cwt. per sq. ft.

Design of Wharves on Soft Ground—continued

Water-level in filling assumed 3-ft. above level of water on seaward side.

Rankine distribution used to obtain toe thrust.

Parabolic distribution used to obtain tié-rod pull.

Bending moment due to eartn pressure and surcharge reduced by factor 0.6, to allow for effect of flexible wall.

Fig. 12 (a) gives the point of inflexion of the sheet-piling and also bending moments due to eartn pressure and surcharge on the one hand and to the differential water-pressure on the sheet-piling on the other hand. The bending moment curves were obtained by treating the sheet-piling as a cantilever and ignoring the effect of the tie-rod. By using the curves in the manner set out in the notes the effect of the tie-rod is allowed for and the bending moments are obtained, a reduction factor being applied, as described above, to the bending moment induced by earth pressure.

The second diagram contains curves to determine the depth of the centre of pressure, to obtain the total thrust, and to obtain the required minimum penetration of the sheet-piling below dredged level. From these the pull in the tie-rod per linear foot of wharf can be obtained, based on parabolic distribution of pressure. The total thrust in the sheet-piling can also be read off. This is based on linear distribution of pressure, which gives the greater value here. When the position of the toe of the piling has been fixed the location of the anchor follows, the depth being obtained from a further curve.

The Author's firm, Messrs. W. T. Halcrow & Partners, were the Engineers for the work at Beira and acted jointly with Messrs. Coode, Wilson, Vaughan-Lee & Gwyther and Messrs. Wolfe Barry, Robert White & Partners as Engineers for the war work.

Post-War Water Transport of Goods

Views of Traders and Industrialists

The following excerpts are taken from the recently issued Report of the Joint Committee of the Association of British Chambers of Commerce and the Federation of British Industries:—

Ocean and Coastwise Shipping

With regard to shipping, it is understood that reports will be submitted to the Minister of War Transport by the Chamber of Shipping at the earliest possible moment, either separately or in a single report for the industry as a whole.

Industry should have an opportunity of expressing its views upon these reports before any decision is made.

With regard to coastwise shipping, however, industry is of the opinion that this form of transport should have rates structures and conditions of carriage.

Canals

Canals have been used in connection with the war effort to a large extent, and form a vital part of the national transport system. It is felt that means should be sought whereby further use of our canals and waterways can be made in the post-war period. Industry feels it is a matter of importance that there should be an improvement of facilities, and, in particular, that the canal system should be brought up to date so that it can accommodate larger and more economical craft. It is noted that certain canal interests have already taken action to secure powers, through Acts of Parliament, to own and operate ocean-going ships, road vehicles, warehouses and aircraft.

Inland waterways should have rates structures and standard conditions of carriage.

Docks

While the work undertaken at all ports is of a similar nature, the governing authorities are very differently constituted. The administration of the ports in some cases is by Public Trust created by Statutory Authority; other ports are owned by municipalities or the railways, while finally there are ports, such as Manchester, which are administered by Statutory Public Companies.

In spite of the large number of ports in the United Kingdom it was estimated in 1936 that fewer than 10 accounted for the bulk of the oversea trade. Ports are of such value in the public interest, not only in connection with the internal trade situation of the country but particularly in connection with export and import traffic, both of which have to meet competition, that very careful consideration should be given to their modernisation in order to put them into a position to offer service as good as, or better than, that offered by foreign ports.

" The power of port undertakings to make charges of a monopolistic character has always been a subject of concern to traders. In cases where port accounts and statistics are accessible by reason of the democratic constitution of the port authority, it is possible for the representations of traders to have a beneficial influence on the equitable distribution of charges. In cases where such accounts and statistics are not available, e.g., some railway-owned ports where charges embrace railway and shipping services—it shall, on request being made to the appropriate Tribunal by an interested party or association, be obligatory on the owners to apportion the charges over the various services in such a manner as may be determined by the Tribunal.

It is recommended that in any reorganisation there should be publication of accounts; also that railway-owned docks should be subject to the same tests as other port undertakings.

" The question of dock charges should be considered, with a particular view to disposing of present anomalies caused by variations in the practice of the various dock undertakings; traders and particularly a body of traders, should have the right of appead to a tribunal against charges which they consider excessive, or which are handicapping them in securing trade.

All forms of transport should have equal facilities at ports and harbours, irrespective of ownership. Railway companies, for example, should not be able, because they own certain ports, to impose restrictions, either directly or indirectly, on the conveyance of traffic by road, or other alternative means of transport to or from such ports.

California Association of Port Authorities

The Annual Meeting of the California Association of Port Authorities was held at Los Angeles in July. The members passed a resolution requesting the United States Maritime Commission to join the Association in making a comprehensive cost survey " to arrive at a determination of rates which will be productive of revenue sufficient to permit ports to propertly maintain their operations."

Mr. A. M. Rosenfeld, vice-president of the Los Angeles Board of Harbour Commissioners, was elected president of the Association for the ensuing fiscal year. Other new officers are: Vice-President, Mr. Thomas Coakley, a member of the San Francisco Board of State Harbour Commissioners; Secretary, Mr. John L. Kelly, President of the Long Beach Board of Harbour Commissioners; and Treasurer, Mr. Fred. B. Parr, President of the Parr-Richmond Terminal Corporation.

Publication

British Railways: Facts and Figures is a handy little compendium of interesting information about the four leading railway companies of Great Britain and the organisation known as London Transport. There is, however, little that concerns ports, a solitary paragraph announcing that the ownership and operation of docks by the railway companies covers harbour and wharf accommodation at 76 places, with an aggregate quayage of 95 miles. The statement that the world's largest graving dock is at the Southampton Docks of the Southern Railway is no longer accurate. The Cape Town Graving Dock, now at the point of completion, exceeds it in dimensions and capacity.

Review

Thames Barrage Scheme Revived

Tideless Thames in Future London, by J. H. O. Bunge, including a Foreword by Lord Desborough, former Chairman of the Thames Conservancy Board, and auxiliary articles by Lieut.-Col. Butler, late Medical Officer of the London County Council, and Sir Charles Bressey, together with four appendices. Pp. 122, with maps, diagrams and photographs. Price: 10s. 6d. net. London, 1944: Published by the Thames Barrage Association and distributed by Frederick Muller, Ltd.

To commence with, a word of commendation is due to Mr. Bunge for the zeal and painstaking industry which has gone to the compilation of this undoubtedly attractive volume, in which are set out in order all the data and arguments collected by him from various sources in support of the scheme for impounding the portion of the estuarial Thames above Woolwich by means of a dam, or barrage, across the river at that point. Mr. Bunge is honorary secretary of the Thames Barrage Association and a wholehearted supporter of the project. We admire his spirited advocacy, while remaining unconvinced of the validity of certain of his claims and being unaffected by his earnest rhetoric, even though backed up by the weighty support of the late chairman of the Thames Conservancy Board and by two expert authorities on health and civic planning.

Charles River, Boston, U.S.A., above Dam.

The outstanding fact is that, however attractive the scheme may appear—and we admit it is attractive—to the Londoner in his civic capacity, all aesthetic and artistic ideal must be set aside and yield first place to purely utilitarian considerations. London is a great city, but it is also a great port and its prominence in the first respect depends entirely on its efficiency in the second. Without the volume of world-wide commerce of its port, London would sink to the level of any large provincial town. Winchester and York have been capitals of England in days gone by, but lacking the nutrition of overseas trade and shipping, they have become relatively insignificant cities. We cannot imagine that Londoners would acquiesce in a similar fate for London. The first thing, therefore, to be done in any re-modelling of the metropolis and its environs is to safeguard the commercial and shipping activities and interests of the port.

From this point of view the barrage scheme exhibits definite and intractable defects. We cannot in a short review go into the whole of the technical issues involved; the more important of them were examined in an Editorial Comment in our issue of July, 1937, and the conclusion then reached was that the scheme was not a practicable one.

To take one point alone, we were not convinced that the proposed installation of lock entrances to the impounded area would, as regards number and capacity, suffice to deal with the great and growing volume of shipping which prior to the war passed through Woolwich Reach daily and which, it is confidently hoped, will continue to increase in the future. It has to be remembered that ships are not like railway trains, capable of running to a precise schedule. They are subject to frequent and unforseeable delays and retardations of movement from various causes: weather conditions principally and fog in particular, which during the winter months may prevail for several days at a time. Then there are seasonal spurts for certain commodities which may cause vessels in those trades to reach the port in abnormal numbers. For these and other reasons vessels may accumulate at the mouth of the river causing temporary periods of high pressure. Any computation, therefore, of a day's working based on yearly averages, is misleading. Moreover, lockings cannot always, or indeed generally, take place with smooth regularity. Bad weather, poor visibility and high winds hinder the rapid manœuvring of vessels in a confined waterway, so that they cannot present themselves in unbroken sequence. Furthermore, inevitable mishaps and occasional breakdowns must be allowed for. There are grounds, therefore—serious grounds, for fearing that the proposed barrage would act as a guillotine, with similar fatal results to the trade of the port.

We will make one final observation. Special attention is called in the volume to certain alleged precedents elsewhere, none of which we consider quite germane to the case in question; at any rate they are not on all fours with the Thames scheme. For instance, the impounding of the Charles River at Boston, U.S.A., is treated as an analogous case. Now we have both seen and admired the placid lake-like surface of that river above the dam, with the verdant water-side embankments and consider it a charming feature of the district, but we must emphasise that the Charles River is not the Thames, nor is the traffic of the Port of Boston, all of which, by the bye, is accommodated below the dam, commensurate with the immense water-borne traffic of London River. Moreover, the Charles River is not the only stream to enter the harbour waters, there is another, the Mystic River, of greater volume and importance: it is, in fact, the Main Ship Channel, while the Charles River is a mere off-shoot.

Apart from its technical arguments, the most essential of which we consider unsound, the book with its array of pictures and diagrams makes interesting and informative reading, and if our readers would like to comply with the Latin dictum: *Audi alteram partem*, we think they will, at least, be agreeably entertained.

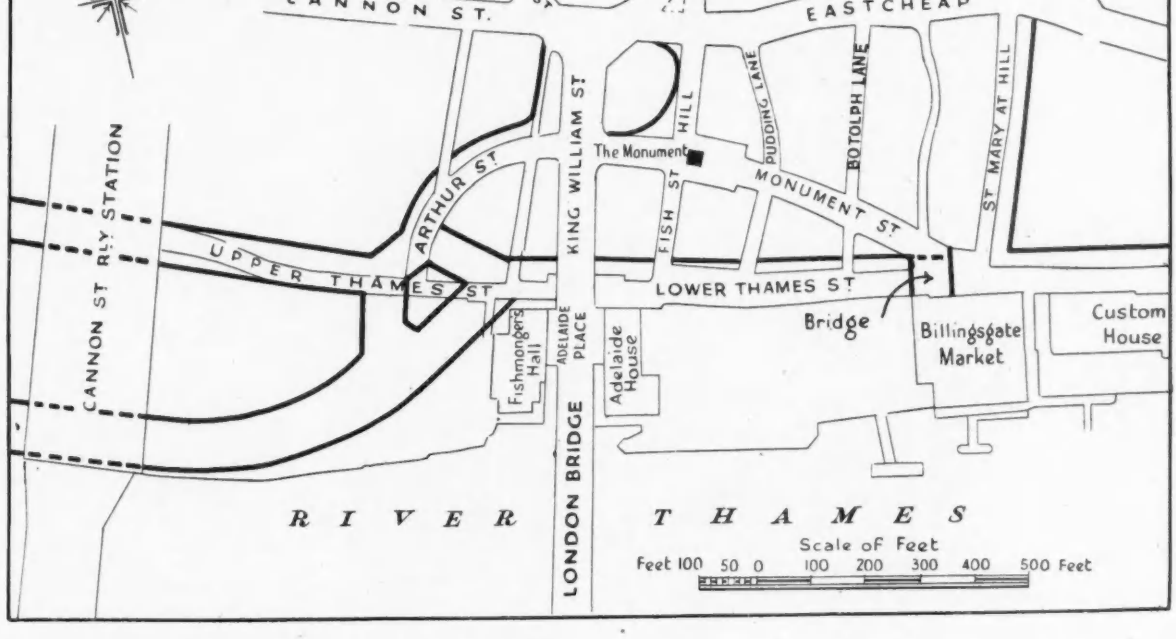
Death of Former Dover Port Officers.

During October there passed away two port officers of note, formerly in the service of the Dover Harbour Board: Captain John Iron, O.B.E., late Harbour Master, and Mr. P. G. Sutton, late Superintendent of Works. Capt. Iron was 86 years of age and had retired in 1938 after more than 40 years' service with the Board. Mr. Sutton had also seen long service and retired in the same year.

Replanning of Thames Frontage

City Corporation's Proposals for Riverside Development

The following is a brief excerpt from the Report prepared by the Improvements and Town Planning Committee of the Corporation of London (which outlines certain proposals for post-war reconstruction of the City), relating to the treatment of the Thames Frontage and particularly that section of it which lies in the vicinity of London Bridge.



After explaining that the main proposal of the Committee consists of a circular or ring traffic route, generally about 80-ft. in width, half to the north and half to the south, the report goes on to say, as follows:—

The southern arm of the ring route continues the Victoria Embankment by passing under Blackfriars Bridge and proceeding eastwards under London Bridge to Tower Hill. Broad issues of policy arise in deciding the ultimate solution that should be adopted in this case and the Committee have examined the three following solutions in some detail:—

(i) An embankment constructed along the foreshore from Blackfriars under Southwark Bridge and joining Upper Thames Street opposite Arthur Street by London Bridge. Such a route would not occupy land at present built upon except at its eastern end, and it could be constructed to allow direct access to the river front from a portion of it by means of lagoon docks. It could be designed to form a dignified river foreground to the City in keeping with the existing Embankment further west and with the south bank (as shown in the County of London plan). As a result of discussions between the City Engineer and the Chief Engineer to the Port of London Authority, the committee were informed that such a proposal would have a detrimental effect on river flow, particularly at Southwark Bridge, where the river is already narrow, and accordingly the committee were compelled to consider alternatives involving the use of building land.

(ii) The first alternative to an embankment on the foreshore is one on the edge of the land next to the river. This, however, involves either the destruction of various large buildings, including most of Vintry House, or major and difficult alterations to such buildings with large loss of floor space, as well as making it difficult, though not impossible, to retain direct river access to buildings.

(iii) The third possibility is that a small stretch of embankment proceeds from Blackfriars to a position between Paul's Wharf and Caldwell Yard, and opposite the intersection of the north-south axis of St. Paul's Cathedral with Upper Thames Street (proposed in connection with the treatment of the environment of St. Paul's Cathedral). At this point an open " place " is designed as an integral part of the view of St. Paul's, which traffic would traverse in order to continue along Upper Thames Street widened to 80-ft.

This scheme preserves the majority of the river front, camp sheetings, moorings, etc., in the City with existing facilities for loading and unloading direct from the water; at the same time it allows of a dignified entrance to the south-west part of the City from the Victoria Embankment, which, treated in architectural harmony with the axial view of St. Paul's, would set a new keynote to the use of that part of the City.

The Committee take the view that London enjoys a privileged situation and facilities as a port, to which the markets of the City are the natural counterpart. " The River has always been the highway into its heart for the world-wide trade on which its greatness and wealth have been founded and maintained. Although the principal docks are east of the City, the riparian rights to the City's foreshore and direct access to warehouses are an integral part of our commerce and trade, and are not to be lightly forfeited. The River is also London's greatest open space, and its beauty should be developed while preserving its utilitarian functions."

Regarding the proposals put forward by the Thames Barrage Association, a matter which has been previously considered by the Corporation and other local authorities fronting the river, as well as by the Committee of Imperial Defence, the Committee do not feel it appropriate to make any recommendation thereon at the present time. It is observed, however, that were these proposals ever to be put into effect it would not be to the detriment or disadvantage of any physical aspect of the plan submitted, nor, they think, would their proposals, if executed, hinder the implementation of such a scheme.

*Hydraulic Model Operation of Lock Mitre Gates**

An Interesting Investigation

By MAURICE N. AMSTER,† Assoc.M.Am.Soc.C.E.

Synopsis

The mitre gate is a commonly used type of closure for the chambers of navigation locks. It is a two-leaf arrangement, comparatively simple in design and adaptable to convenient means of operation. In the open position the two leaves are recessed in opposite lock walls with their faces parallel to the walls. For closure each leaf is swung about a vertical axis near its downstream (quoin) end so that the upstream (mitre) ends of the leaves contact at the centre line of the lock. The bottoms and the quoin ends of the leaves are equipped with sealing arrangements that contact floor and lock walls when the leaves reach their closed positions. In supporting a water load, the gate acts as a three-hinged arch, with the two quoin bearings and the mitre bearing forming the hinges and the lock walls acting as abutments for the end thrust. The quoin end of each leaf is supported at the bottom by a pintle assembly and at the top by a gudgeon assembly. Frequently used types of operating machines are: Hydraulic cylinder and piston, cable and drum, and crank and strut.

In the design of machinery for the operation of lock mitre gates, it is essential to know, as accurately as possible, the power requirements and the loads that will occur on the operating mechanism throughout the cycle. For lack of better data, designers in the past have had to resort to empirical methods usually based upon arbitrary assumptions as to hydraulic resistance. Mechanical difficulties in operation generally have been avoided by the use of large safety factors. In the design of the operating machinery for the gates of the Third Locks of the Panama Canal, the size of the leaves indicated that the forces to be encountered would exceed those in any similar structures in the past. Because of the large number of machines required, the use of high safety factors would have been extremely uneconomical. Accordingly, it was decided to conduct model tests to investigate the resisting forces that might be expected in the operation of the Third Lock gates.

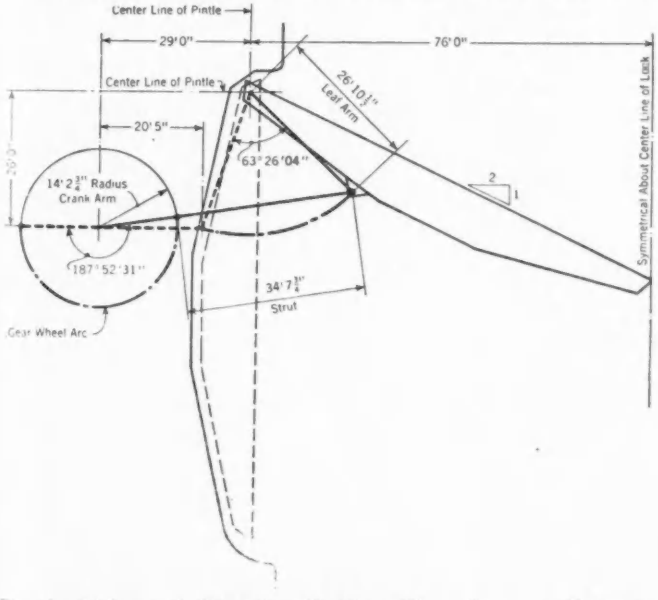


Fig. 1. Linkage of Operating Machine (Dimensions are Prototype Values; Scale, 25:1).

The Prototype

The mechanism designed for operating the prototype gates is of the crank-and-connecting-rod type, having kinematic characteristics similar to those used in the existing Panama Canal Locks, but differing in mechanical details and arrangement. A large gear-wheel, driven by two electric motors through trains of speed-reduction gears, rotates a vertical shaft at practically uniform velocity. A crank is keyed on the lower end of the shaft, and a strut is linked to the end of the crank and to the face of the gate leaf. The operating linkage is shown schematically in Fig. 1. The crank arm is driven through an arc of 187° 52′ 31″ to move the gate leaf through an angle of 63° 26′ 4″. The dead-centre positions of the crank relative to the strut coincide with the extreme positions of the gate leaf, effecting an infinite theoretical mechanical advantage at those positions.

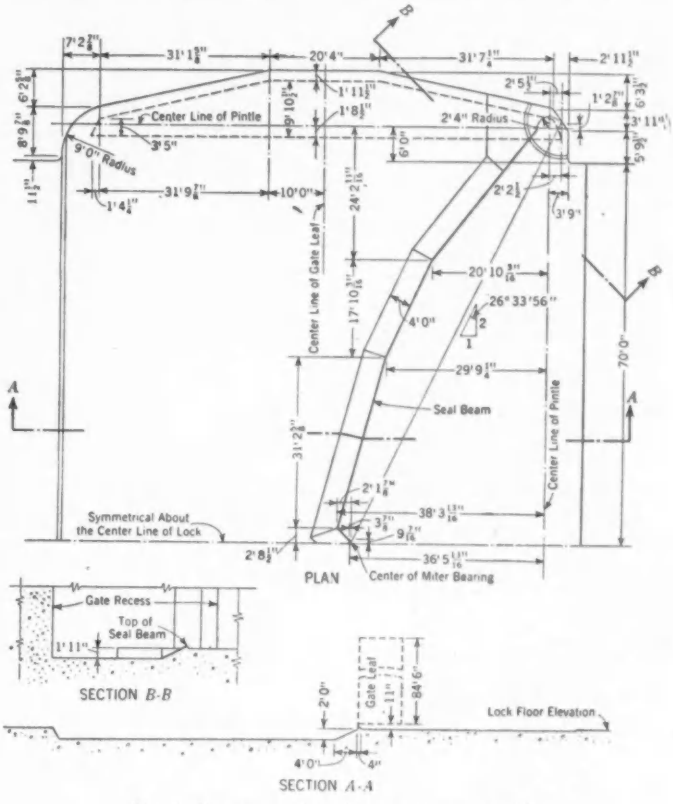


Fig. 2. Prototype Gate Bay, Recess and Sill.

The Model

The model lock, constructed of concrete to a scale of 1 to 25, consisted of a gate bay located in a flume of sufficient length to permit simulation of the lock chamber for distances of 1,125-ft. upstream and 625-ft. downstream. Details of the gate bay are shown in Fig. 2. The gate leaves were constructed of an angle-iron framework faced with galvanised sheet metal. Holes bored in the tops and the bottoms of the leaves permitted water to flow easily into or out of the leaves during changes of the water-surface elevation in the flume. The weight of the prototype leaves was not simulated.

The model leaves were operated by the mechanism shown in Fig. 3. The position of each linkage relative to its leaf was displaced 180 degrees about the vertical pintle axis for convenience in the model. An electric motor drove two speed reducers with crank arms keyed to their vertical shafts. Each model strut was pin-connected at one end to a crank arm and at the other end to an arm keyed to a vertical alloy-steel shaft 1¼-in. in diameter. This shaft transmitted the driving torque to the leaf.

*Reproduced from the Proceedings of the American Society of Civil Engineers, March, 1944, p. 303 et seq.

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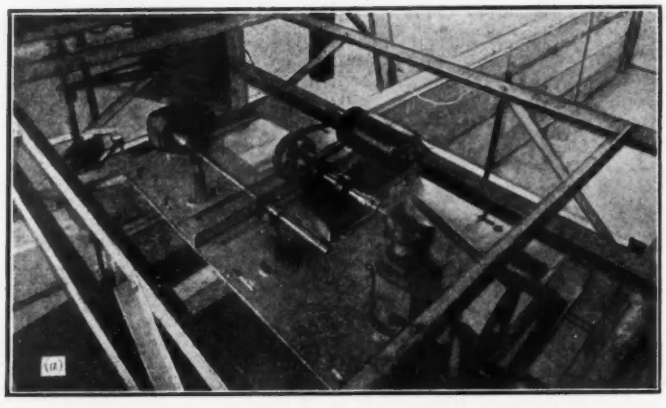
Hydraulic Model Operation of Lock Mitre Gates—continued

The torque applied to one of the leaves during operation was determined by measuring the twist produced in a reduced section of the drive shaft. The diameter of the reduced section of each shaft was 0.6-in. Details of the measuring apparatus are shown in Fig. 4. A hollow cylinder was keyed to the drive shaft just below the reduced section, and a horizontal arm was bolted to a flange on the top of the cylinder. On another horizontal arm, which was keyed to the drive shaft just above the reduced section were mounted two dial gauges graduated to indicate linear deflections to the thousandth of an inch. The gauge plungers were in contact with the arm attached to the cylinder and thus were actuated by the relative movement of the the two arms. A value obtained with this arrangement was not exactly a measure



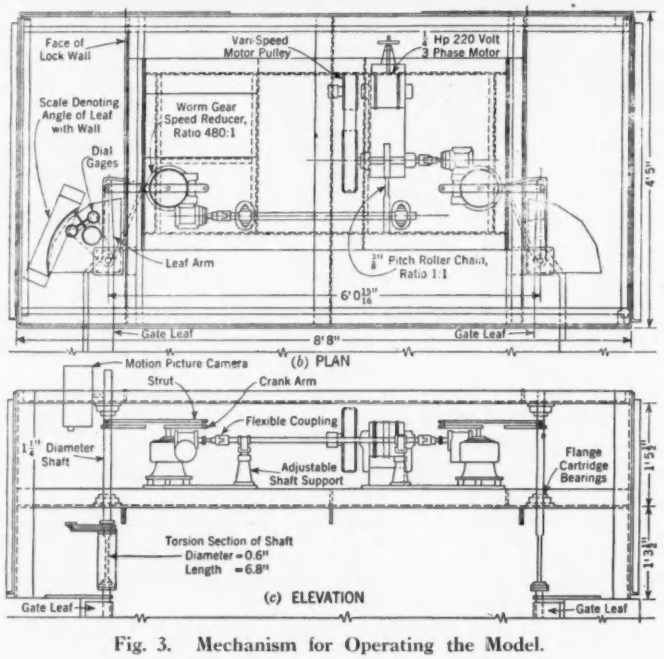


Fig. 3. Mechanism for Operating the Model.

of the twist arc, but the difference between a reading and the actual length of the corresponding twist arc was so slight that calibrations of the reduced section over a range considerably greater than that of the tests did not deviate appreciably from straight-line relationship. The twist in the section of the shaft below the point of attachment of the cylinder was negligible.

An extension of the arm attached to the cylinder indicated the angular position of the gate leaf on a segmental scale. Instantaneous values of leaf angle and dial-gauge reading were obtained during an operating cycle with a motion-picture camera attached to the drive shaft above the measuring apparatus.

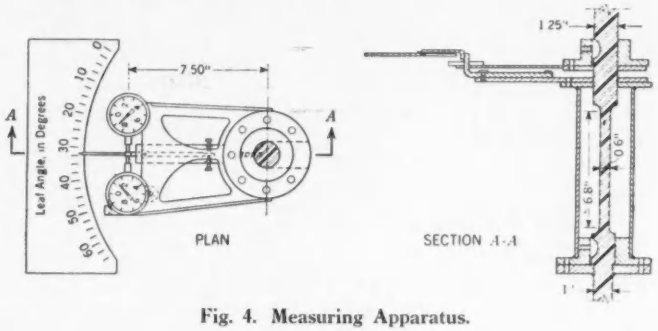


Fig. 4. Measuring Apparatus.

Operating dimensions of the model were derived from prototype values on the basis of Froude's law, as follows:

Dimension	Ratio, prototye to model
Length and depth	25 : 1
Volume, weight, and force	15,625 : 1
Time and velocity	5 : 1
Torque	390,625 : 1

Numerical values stated in this paper are in prototype dimensions.

Testing Procedure

The water level in the flume was adjusted to submerge the gate leaves to the desired depth. Fresh water, only, was used in the tests. The operating speed was adjusted by means of the vari-speed pulley arrangement to complete an operating cycle in the required time. It was established by numerous trials that, for a fixed vari-speed pulley setting, the duration of the cycle varied less than one second, other conditions remaining unchanged. The dial gauges were set at zero, the motion-picture camera was started, and finally the operating mechanism was started. When the gate reached its terminal position, the mechanism was stopped by a limit switch, and, after allowance of time for the subsidence of eddy currants or surges, the operation was repeated for the reverse direction.

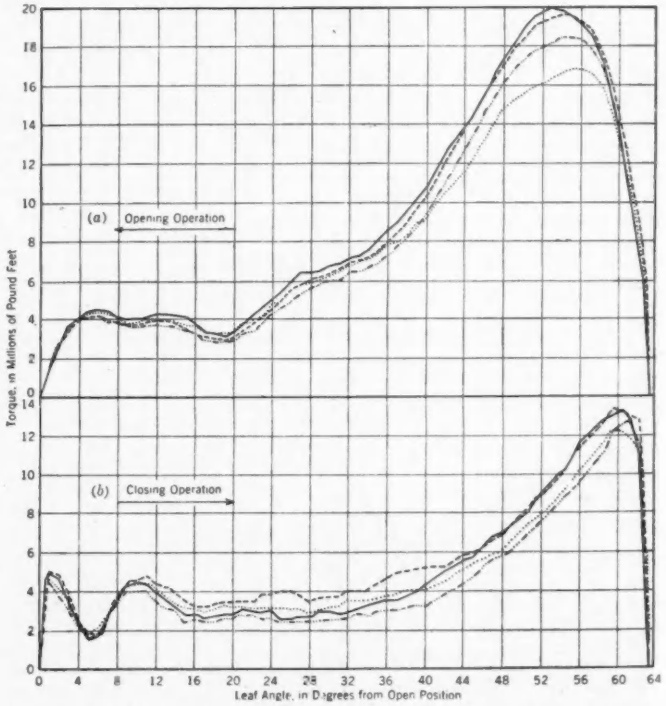


Fig. 5. Model Consistency, Base Conditions (Operating Conditions Constant).

Hydraulic Model Operation of Lock Mitre Gates—continued

Tests

The conditions believed to involve maximum hydraulic resistance in the operation of the prototype gates were: Synchronous operation of the two leaves, submergence of 82.5-ft., upstream chamber length of 1,105-ft., and downstream chamber length of 200-ft. These, together with an operating time of two minutes (which had been selected tentatively) were used as base conditions. The following conditions were tested to determine their individual effects upon the resisting torque: Nonsynchronous operation (differences in starting time of the two leaves from 0 to 20 seconds), submergences from 45 to 82.5-ft., upstream chamber lengths from 300 to 1,105-ft., operating times from 1.75 to 2.75 minutes, two gate-leaf weights—2,000 tons and 2,400 tons, and single-leaf operation.

Test Results

In all tests, a clearly defined peak torque value was reached in the vicinity of the mitred position of the gate. For each set of operating conditions, peak opening torque was considerably greater than peak closing torque. (This does not include the single-leaf tests, which produced only moderate torque peaks.)

The results of base tests repeated throughout the testing programme are compared in Fig. 5. Operating conditions were maintained identical for the base tests: Operating time, two minutes; submergence, 82.5-ft.; upstream length of chamber, 1,105-ft.; and downstream length of chamber, 200-ft. The extreme deviation from average is about 1,500,000 lb-ft. or 8.1% in the opening operation and about 500,000 lb-ft. or 3.8% in the closing operation.

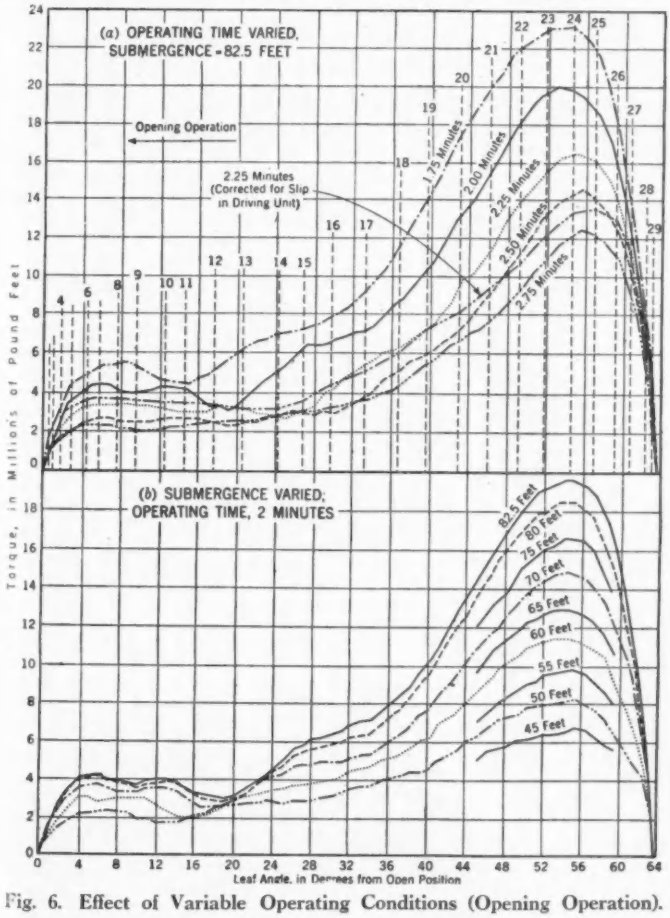


Fig. 6. Effect of Variable Operating Conditions (Opening Operation).

The effect of speed variation in Fig. 6 (a), and the effect of variable submerged depth is shown in Fig. 6 (b). With the relatively short chamber on one side of the gate, variation of the length of the chamber on the other side had no appreciable effect on the torque for lengths greater than 625-ft. Curves, similar to those in Fig. 6, for these variations indicated that the effects of chamber length were of minor importance compared with those of speed and submergence.

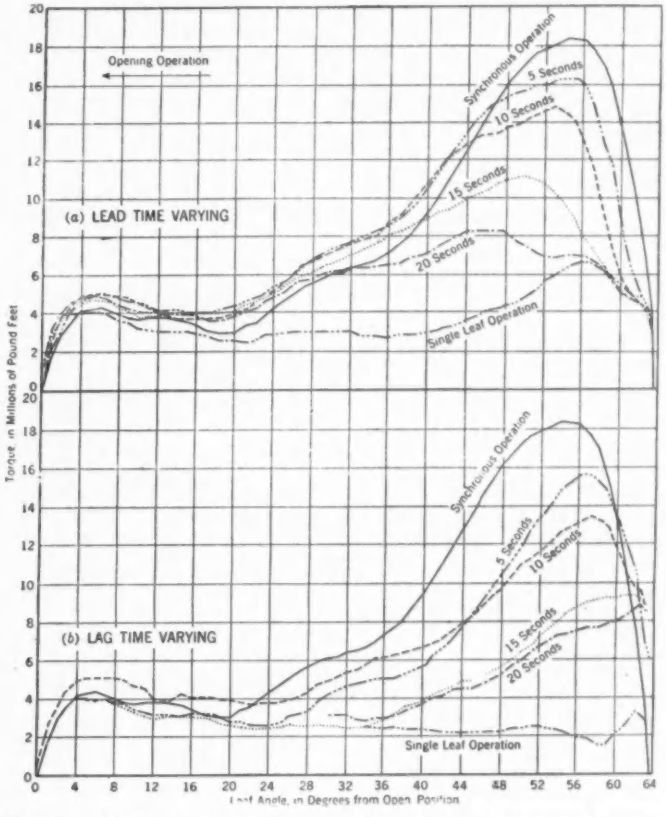


Fig. 7. Effect of Nonsynchronous Operation of Leaves (Opening Operation, Base Conditions).

Likewise, the effect of an increase of 20% in leaf weight was not sufficient to be revealed by the model tests. The addition of weight increases the mechanical frictional resistance and the inertial resistance to acceleration, but generally the forces required to overcome bearing friction and inertia are quite small relative to the total resisting force. The angular acceleration of the prototype gate leaf was calculated to be about 0.00019 radians per second per second at the time of indicated peak torque, an the moment of inertia about the axis of rotation was estimated to be about 208,000,000 slug-ft². Therefore, the torque necessary to accelerate the leaf at peak-torque position would be 208,000,000 × 0.00019 = 39,500 lb-ft. Since the peak torque values in the opening operation of the base tests ranged from 17,000,000 to 20,000,000 lb-ft. (Fig. 5 (a)), the inertial component is only about 0.2% of the total.

Fig. 7 demonstrates that the torque was lowered considerably in the vicinity of the peak values by delaying the starting of one leaf. It is observed that a 20-second delay reduced the peak values about 50%. Comparison of Figs. 7 (a) and 7 (b) indicates that the leaf farthest from the mitred position always required the greater peak of operating torque.

Verification Tests

Prior to the initiation of the model tests just described, tests had been conducted on a mitre gate of the existing Panama Canal Locks to obtain data from which approximate load values for Third Locks gates could be derived for preliminary design purposes. Because of the availability of these data, the model constructed for tests on the Third Locks gates was used, with certain necessary alterations, for verification tests on the operation

Hydraulic Model Operation of Lock Mitre Gates—continued

of the gate of the existing locks. The gate pintles in the Third Locks, as designed, are farther apart than those in the existing locks, but to simplify the alterations, the locations of the pintle bearings in the model were not changed, and a scale ratio of 1 to 18.813 was obtained for the verification tests. Space limitations prevented model reproduction of the lock-chamber lengths upstream and downstream from the prototype gate.

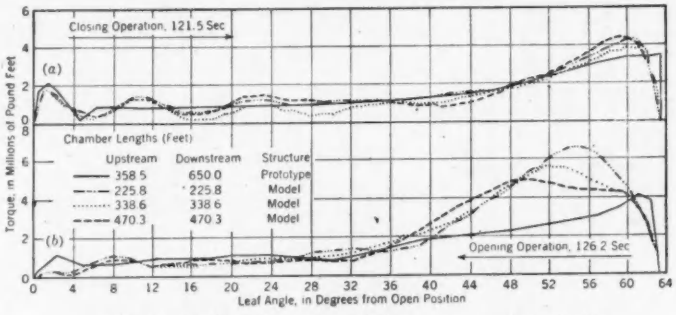


Fig. 8. Verification Tests (Submergence, 73.16 Feet).

The tests conducted on the prototype gate of the existing locks consisted of measurements of power input to the driving motor of one of the gate machines during opening and closing operations. The characteristics of the motor were determined separately by means of Prony-brake tests. By taking into account the gear reduction, the mechanical advantage of the crank-and-strut linkage at the recording intervals, and the probable mechanical efficiency, the power-input readings were converted into values of torque about the axis of rotation of the gate leaf.

The results of model and prototype tests are shown in Fig. 8. The prototype data represent the average of five test runs, and the model data represent a single run. In all cases, the peak torques observed in the model tests were larger than those recorded in the prototype tests and occurred farther from the mitred position of the gate leaf. The verification is reasonably close for the closing operation but not for the opening operation. There are several factors that could have contributed to the disparity:

(a) The driving motor of the model machine had negligible slip. The slip of the prototype motor was found to be very high at the position of peak resisting torque, and the consequent deceleration would tend to reduce the resisting torque.

(b) In the prototype tests, it was observed that the two gate leaves did not start or finish their movements simultaneously, even though the operating machines were started simultaneously. The full importance of this condition, which is probably attributable to a difference in the characteristics of the two motors, was not known at the time of the prototype tests, but is influence was demonstrated by the results of the model tests on the Third Locks gate with unsynchronized operation of the leaves (Fig. 7). Delay in starting a leaf in the opening operation reduces the peak load and delays its occurrence.

Conclusions from Tests

Three conclusions are derived from the foregoing:

1. When the two leaves are operated together, peak resistance occurs in the early part of the opening cycle;

2. The peak load can be reduced considerably by delaying the starting of one leaf, but the best load distribution for simultaneous operation of the leaves, whether synchronized or not, can be obtained by the use of an operating cycle involving low speeds at the extremes of travel—especially near the mitred position; and

3. Peak torque varies directly as operating speed and submerged depth of the gate.

Application of Test Results to the Prototype Design

Factors not represented in the model tests were: Hydraulic drag, mechanical friction, transient surge phenomena, salinity heads, and speed variations in the driving unit.

The hydraulic drag and the mechanical friction forces were assumed to be negligible relative to the total resisting force. Opposing surge heads that might exist at the time a gate is operated and the effect of waves produced by external influences such as wind and ship movement were not considered to be practical of reproduction in the model tests. The determination of the probable magnitude of salinity heads and the correction of test results for the effect of slip in the driving units will be discussed herein.

Notation.—The following letter symbols, used in the paper, conform essentially to American Standard Symbols for Hydraulics, prepared by a Committee of the American Standards Association, with Society representation, and approved by the Association in 1942:

c = distance of the culvert roof from the lock floor (see Fig. 9);
F = force per unit length of gate:
- F_f = force on the fresh-water side of the gate;
- F_n = net unbalanced force;
- F_s = force on the salt-water side of the gate;

T = torque:
- T_a = torque about the axis of rotation;
- T_g = torque at the gear input shaft;

y = depth:
- y_d = downstream, or salt-water depth to the lock floor;
- y_f = depth of water to the equal-pressure plane on the fresh-water side of the gate;
- y_s = depth of water to the equal-pressure plane on the salt-water side of the gate;
- y_u = upstream, or fresh-water depth to the lock floor;

γ = specific weight:
- γ_f = fresh water;
- γ_s = salt water.

Forces Due to Salinity Head.—When the specific gravity of the water on the two sides of a closed lock gate is not the same—a situation encountered at ocean locks supplied with lockage water from a fresh source—the attainment of flow equilibrium in the connecting culvert system is very unlikely to balance the total hydrostatic forces on the two sides of the gate. When the fresh or comparatively fresh water is on the upstream side of a closed mitre gate, the direction of the unbalanced hydrostatic force is such as to oppose the opening of the gate, as illustrated in the following analysis.

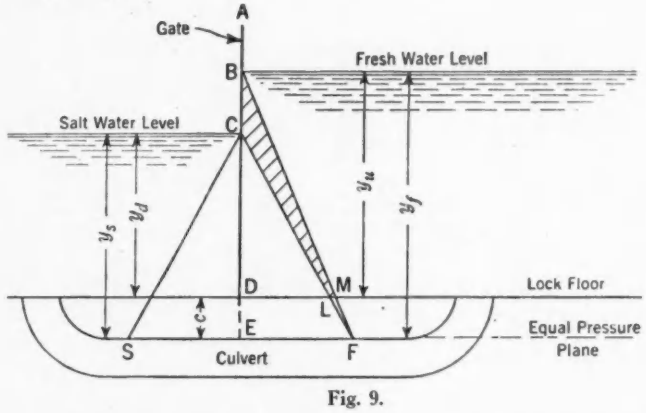


Fig. 9.

Fig. 9 is a diagrammatic section parallel to a lock chamber, with the gate represented by the line AD and the pools on the two sides of the gate connected by a culvert running below the level of the gate bottom. For equilibrium to exist and flow to cease, there must be a plane of separation between salt water and fresh water at which the pressure is balanced. Since salt water is heavier than fresh water, the lower part of the culvert will be filled with salt water at least up to the level of the culvert roof. It will be assumed tentatively that the equal-pressure plane is at the same level as the culvert roof.

The pressure diagrams for the two sides of the gate are represented by lines CS and BF, with ES equal to EF. The area BCLM represents unbalanced pressure on the fresh-water side of the gate.

By definition (see notation):

Hydraulic Model Operation of Lock Mitre Gates—continued

$$F_f = \frac{\gamma_f y_u^2}{2}\ ;\ \text{and}\ F_s = \frac{\gamma_s y_d^2}{2} \quad \ldots\ldots(1)$$

The net unbalanced force per unit length of gate equals

$$F_n = \frac{\gamma_f y_u^2 - \gamma_s y_d^2}{2} \quad \ldots\ldots(2)$$

Since $y_u = y_f - c$ and $y_d = y_s - c$ (see Fig. 9), Eq. 2 becomes:

$$F_n = \frac{\gamma_f (y_f - c)^2 - \gamma_s (y_s - c)^2}{2}$$

$$= \frac{\gamma_f y_f^2 - 2\gamma_f y_f c + \gamma_f c^2 - \gamma_s y_s^2 + 2\gamma_s y_s c - \gamma_s c^2}{2} \quad \ldots\ldots(3)$$

For the condition of equilibrium,

$$\gamma_f y_f = \gamma_s y_s \quad \ldots\ldots(4)$$

Substituting Eq. 4 in Eq. 3 reduces the force equation to

$$F_n = \frac{\gamma_s y_s (y_f - y_s) - c^2 (\gamma_s - \gamma_f)}{2} \quad \ldots\ldots(5)$$

With the value of y_s known, y_f can be determined from Eq. 4 for assumed values of γ_f and γ_s. With the substitution of $\frac{\gamma_s y_s}{\gamma_f}$ for y_f, Eq. 5 reduces to

$$F_n = \frac{\gamma_s y_s^2 (\gamma_s - \gamma_f)}{2\gamma_f} - \frac{c^2 (\gamma_s - \gamma_f)}{2} = \frac{\gamma_s - \gamma_f}{2}\left(\frac{\gamma_s y_s^2}{\gamma_f} - c^2\right) \quad \ldots\ldots(6)$$

When the connecting culvert is above the level of the gate bottom, Eq. 6 applies without change. If the equal-pressure plane is at the level of the gate bottom, c of Eq. 6 equals 0, and

$$F_n = \frac{\gamma_s y_s^2 (\gamma_s - \gamma_f)}{2\gamma_f} \quad \ldots\ldots(7)$$

In the application of the developed formulas to the prototype, several factors ordinarily would enter into the decision as to which gate would be used as a criterion and into the assumption of salinity values. If no factual data were available, it would be logical to base the computations on the gate that will have the greatest operating submergence and to assume sea water with a specific weight of 64.0 lb. per cu. ft. on one side and fresh water with a specific weight of 62.5 lb. per cu. ft. on the other side. However, at the existing Panama Canal Locks, which correspond closely with the designed prototype locks and which connect the same bodies of water, information was available as to the location at which the greatest difficulty is encountered from salinity pressures, and the maximum salinity head measured at that location is about 0.7 ft. At the corresponding location in the Third Locks, the maximum salt-water depth to the lock floor on the downstream side of the gate is 68.9-ft., and the lowest culvert roof is 9-ft. below the floor. The water on the downstream side is assumed to have a specific weight of 64.0 lb. per cu. ft. If the salinity of the water on the upstream side were assumed to be uniform for the full depth to the culvert roof, Eq. 6 would apply, but, for a given head difference, the worst condition obviously would be represented by the assumption of sea-water salinity on the upstream side from the lock floor down and a uniform lower salinity from the lock floor up, since pressure difference below the floor does not act on the gate. With this assumption, $y_2 = 68.9$-ft. and $y_f = 68.9 + 0.7 = 69.6$-ft. Therefore $\gamma_f = 63.3$-lb. per cu. ft.

As indicated by this result, entirely fresh water probably will not be found on one side of a gate with undiluted sea water on the other side. Such a condition is prevented by the fact that every time the gate is opened, the sea water on one side displaces a large portion of the fresh water on the other side because of the difference in weight.

The prototype gate leaf is about 84-ft. long from mitre end to axis of rotation. Neglecting the small area from the axis of rotation to the quoin end and substituting in Eq. 7, the total force on the gate leaf is computed as 141,000 lb. The moment arm of this force about the axis of rotation of the leaf is equal to half the length of the leaf. Therefore, the moment resisting opening of the leaf is ½ by 84 by 141,000 = 5,920,000 ft.-lb.

Correction of Test Results for Slip in Driving Unit.—The model machine was driven by a relatively high-powered motor that produced a practically constant speed for the reduction gear and the operating crank. In the designed prototype machine, however, power is to be transmitted from motors to reduction gears through hydraulic couplings. Therefore the speed variations to be expected in the prototype machine must be taken into account in application of the model test results.

Although most of the model tests were conducted with an operating time representing two minutes in the prototype, the operating time later selected for the prototype was 2.25 minutes. A tentative selection was made of motors, hydraulic couplings, and reduction gears such that, with the motors operating at rated full-load speed through the entire operating cycle, and taking into account the slip of the couplings, an operating time of approximately 2.25 minutes would result. The motor and the hydraulic coupling were of standard design, and their slip characteristics were available from manufacturers. For the purpose under discussion, the two slip characteristics were combined. Fig. 10 shows the speed of the output shaft of the hydraulic coupling for the torque range from no load to the breakdown load of the coupling, with the slip of the motor included.

The travel of the gate leaf between recessed and mitred positions was divided for convenience into thirty parts corresponding to thirty equal divisions of the arc of crank movement. The relation of these divisions with respect to angular position of the leaf is shown by the vertical lines in Fig. 6 (a). Thus, for each position, the resisting torque about the axis of rotation of the leaf is indicated for five different operating times. On the assumption that the crank rotates at uniform speed throughout an operation, each operating time corresponds to a certain speed at the input shaft of the reduction gear. By computing trigonometrically the mechanical advantage of the crank-and-strut linkage for each position, taking into account the total gear reduction, and assuming a mechanical efficiency, the resisting torque at the input shaft of the reduction gear can be derived for each operating speed.

Leaf Position 18 will be taken as an illustration. For this position the mechanical advantage of the crank-and-strut linkage was calculated to be 1.92. The total gear reduction was 5,660 to 1, and the over-all mechanical efficiency, derived from assumed efficiences for individual parts of the machine, was 89.4% Therefore, the torque required at the gear input shaft to produce a given torque about the axis of rotation of the leaf was obtained by dividing by the factor (1.90 × 5,660 × 0.894 =) 9,715. With Ta representating the torque about the axis of rotation and Tg the corresponding required torque at the gear input shaft, the values in Table 1 were derived for the opening movement from the torque values shown in Fig. 6 (a) for Position 18. The speed torque relationships are plotted in Fig. 10 to the same co-ordinates as the hydraulic-coupling characteristic. Since the output torque of the hydraulic coupling must be the same as the resisting torque at the gear input shaft, the intersection of the curve for each leaf position with the hydraulic-coupling characteristic represents corrected torque and speed for that particular leaf position. Thus the corrected torque at the gear input shaft is 620 lb.-ft., and the corrected speed is 637 r.p.m. The torque at the gear input shaft may be multiplied by the conversion factor 9,715 to obtain a corrected value of torque about the axis of rotation. This gives 6,020,000 lb.-ft.

TABLE 1. Data from Speed-Torque Tests, Opening Movement.

No.	Description	Operating time, in minutes				
		2.75	2.50	2.35	2.00	1.73
1	Speed at gear input shaft (r.p.m.)	545	589	655	736	818
	Torque, in pound-feet:					
2	T_a, about axis of rotation (millions)	4.4	5.1	6.4	8.8	11 7
3	T_g, at the gear input shaft ...	453	535	659	905	1,205

This method was used to derive torque and speed values for each of the thirty positions for both the opening movement and the closing movement, and, from these values, crank-and-strut loads and motor horsepower were computed. The corrected values of torque about the axis of rotation for the opening move-

Hydraulic Model Operation of Lock Mitre Gates—continued

ment are shown in Fig. 6 (a) for comparison with the uncorrected model test results.

To determine the probable operating time, the average speed of the crank between each pair of consecutive positions was assumed to be equal to the average of the corrected speeds at the two positions. The total operating time calculated on this basis differed only a negligible amount from the desired 2.25 minutes, and the tentatively selected driving unit was adopted for the machine.

The correction method used is an approximate one, of course. The basic assumption was made that the speed-torque relationships indicated by the model test results for any given leaf position would hold true independently of speed variations at other positions. This assumption cannot lead to very accurate results, but the degree of accuracy probably is sufficient for the purpose of the computations.

Capacity of Machines.—All gates of the prototype will be operated by identical machines designed for the operating conditions at the gate with the greatest potential load. This load was assumed to be represented by the test results shown in Fig. 6 (a). It was unnecessary to make additional allowances for salinity forces; at the gate where salinity is most likely to affect operation, the submergence is only about 70-ft., and, since the machines are designed to operate a gate submerged 82.5-ft., an ample reserve capacity is available (see Fig. 6 (b)). The hydraulic coupling acts as a load-limiting feature, and, if salinity pressure exceeds expectations, the coupling slip will increase automatically, decelerating the opening movement until the salinity head has been dissipated by flow between the gate leaves. The operating strut is equipped with a shock absorber to dampen the effect of any transient loads such as waves. The shock absorber contains a limit switch that will stop the driving motors before the strut can be overloaded.

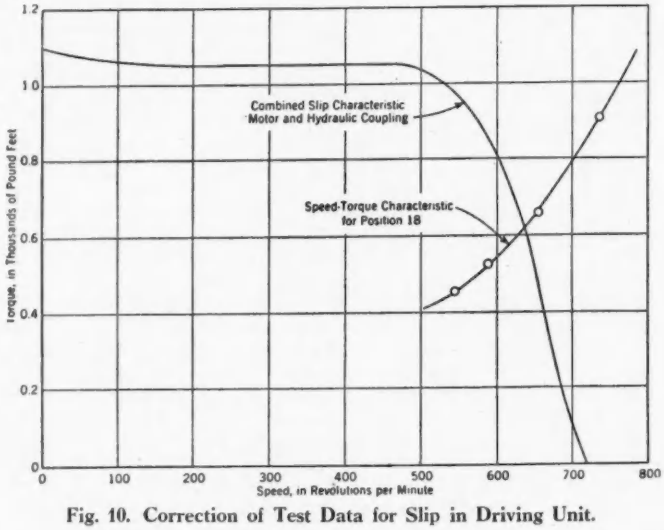


Fig. 10. Correction of Test Data for Slip in Driving Unit.

Application of Test Results to Other Mitre Gates

The data obtained from the model tests probably could be applied to other mitre gates having the same kinematic cycle. This would require correlation of scalar ratios with the relationships derived from the tests. The length of a gate leaf would determine the linear scale ratio with respect to the leaf of the test gate, which is 84-ft. long. For example, if a gate leaf is 42-ft. long, the linear scale would be 1 to 2. If the submergence is 30-ft., the curve in Fig. 6 (b) representating a 60-ft. submergence would be applicable with all torque values divided by 24, or 16. If the operating time is greater or less than 2 minutes, the appropriate curve of Fig. 6 (a) is used and corrections are made for a number of leaf positions in accordance with the ratios in Fig. 6 (b) between the torque values at a 60-ft. submergence and those at an 82.5-ft. submergence.

If it is necessary to correct for slip in the driving machine, new speed-torque curves should be derived from those of Fig. 6 (a) on the basis of the scale relationships and the submergence ratio, and the correction method should be applied as outlined herein.

In this application, differences in chamber lengths are neglected. However, unless such differences are great, their effect may be relatively unimportant.

Acknowledgment.

At the time of the tests described in this paper the Special Engineering Divison of The Panama Canal was directed by T. B. Larkin, M.Am.Soc.C.E., supervising engineer. The investigation was conducted by the Hydraulic Section of the Division under the direction of F. W. Edwards, M.Am.Soc.C.E., senior hydraulic engineer and later, E. Soucek, Assoc.M.Am.Soc.C.E., senior hydraulic engineer. The model operating mechanism was designed by G. D. Smith, engineer, of the Mechanical-Electrical Section. The writer was in charge of the investigation.

The Use of Timber in Port Structures

Views of a Timber Expert

The following is an extract from a Paper, entitled " Timber in Shipbuilding," read at a recent joint meeting of the Institution of Naval Architects and the Institution of Engineers and Shipbuilders in Scotland, by Mr. E. H. B. Boulton, Technical Director of the Timber Development Association:

Dock Construction

For dock and wharf construction, sluice gates, etc., timber is the best material. There are many advantages in the use of timber for water-front purposes, among them being—

1. Lowest initial cost.
2. Lowest cost per year of useful life.
3. Quickest erection.
4. Ease of modification and alteration to suit changing needs of shipping.
5. Salvage value of creosoted timber and piling at the end of a useful life.
6. The pile structure does not materially affect the currents and eddies about a wharf, as would a solid construction.
7. Timber pile wharves are more elastic. Shipowners will shun wharves that put all the destructive force of impact on their ships.

With modern methods of preservation there is little fear of damage from marine borers or decay, and both in this country and the United States of America many marine structures in timber are giving good service after 40 years. The full-cell method of treatment should be used for this type of work, that is, the forcing in of all the coal tar creosote that the piling can be made to hold without causing serious damage to the wood. For the highest absorptions it is necessary to air-season the piling before treatment. Timbers such as Douglas fir, in which the penetration of preservatives is usually uneven, should be treated by incising before impregnation to permit deeper and more uniform penetration. To accomplish this, sawn or hewn material is passed through a machine having horizontal and vertical rollers equipped with teeth that sink into the wood to a predetermined depth.

Modern connectors consist in general of metal rings or plates that, embedded partly in each of adjacent members, transmit the load from one to the other. There are many types of variations of such connectors, the best known being the split ring, bulldog and toothed ring. The use of these connectors increases the strength of bolted timber joints (sometimes up to 100 per cent. or even more), and considerably reduces the danger of bolt holes becoming oval—so weakening the joints. There have been great developments in the use of connectors during recent years, especially in America, as appreciable saving of timber by the use of smaller sections can be obtained by this method of jointing.

Invasion Harbours

Pre-fabricated Structures Utilised for Allied Landings

The following particulars have been issued to the press respecting the artificial protection works used on French beaches, for landing supplies for the invasion armies. They were prepared in advance of D Day, towed across the English Channel, and sunk in selected positions:—

Preliminary Arrangements

The plan originally accepted was that two artificial ports, one in each sector, British and American, should be made, each consisting of a breakwater formed of concrete caissons. The War Office undertook to produce the caisson designs. In spite of the great quantity of work to be done, and such essential experiments as the effect of wave action on the design, which were carried out at the National Physical Laboratory, sufficient working drawing were produced by October 4th and the final drawings were substantially completed by October 20th, all details being finished by November 27th. The execution of the work was placed in the hands of the Ministry of Supply on September 24th, 1943.

To accommodate the necessary shipping and port equipment, the size of each harbour had to be roughly the same as Dover, which entailed the construction of 150 caissons. These could not be placed in water deeper than 5½ fathoms, which meant that only a limited number of ships, such as the Liberty type, could use the harbour. It was therefore decided to make an outer floating breakwater in addition, and this task, including experiment, design, and production, was undertaken by the Admiralty.

In January, 1944, it was realised that the number of tugs likely to be available was less than the demand. This meant slowing down the rate of construction of the harbours, and increasing the risk of interference by bad weather. In order to provide an immediate shelter for the host of small craft it was then decided to make five short breakwaters formed of blockships along the invasion coast. Two of them would be incorporated in the artificial ports. Sixty ships were earmarked by the Ministry of War Transport, including some warships, such as H.M.S. *Centurion* and the French battleship *Courbet* and the Netherland cruiser *Sumatra*, giving a total length of about 24,000-ft. of breakwater.

The arrangement of the breakwater on the ground was based on old French charts, which were thought to be unreliable because of the changes in the sea bed. These were corrected to some extent by actual reconnaissance and soundings taken during the period before D Day.

Operations on Site

In the operation the first arrivals on the far shore were the blockships, all of which, in spite of their age, made the crossing close behind the assault forces and arrived safely. They were sunk by explosive charges, and their Naval and Merchant Navy crews were then brought back. The whole of this part of the operation was completed successfully during the five days following D Day, and provided some very valuable shelter on the beaches.

Meanwhile the concrete caissons, floating breakwaters, and piers were being towed across at an average speed of 4 knots, the total distance being over 100 miles. All the pieces towed very well in spite of their awkward shapes, except for the lengths of pier, which had to be treated very tenderly in the choppy weather experienced. The total tug fleet available for towing the equipment was 85. A minimum of 210 tows was required, involving a weight of over 1,000,000 tons allowing for few losses by enemy action, and each round trip was expected to take three days. There was very few losses of tugs, and they carried out this unusual, strenuous, and sometimes dangerous task with great patience, courage, and skill.

On arrival the concrete caissons had to be sunk accurately in places selected as a result of surveys made by a special party landed on D Day. In spite of the difficulty of picking the exact spot, the operation was carried out very successfully. By D Day plus 12 more than half the caissons were in position, and the harbours were already an impressive sight.

Similarly, advanced parties in special ships arriving on D Day had laid heavy moorings in deep water to which the floating breakwaters were attached as they arrived. This operation was complete by D Day plus eight.

Up to D day plus 12 the operation was going according to plan, but the next day a gale blew up from the north-east which continued for three days, the worst June gale experienced for 40 years. It came from the worst possible direction, as the harbours were exposed to its full force. Unfortunately it caught the the harbours at the half-way stage. The American harbour suffered most severely, as it was in a more exposed site, and the breakwaters were largely broken up, so much so that this, combined with the capture of Cherbourg, caused the work on this harbour to be discontinued. The British harbour was protected to some extent by the Calvados reef and suffered far less damage, from which it was soon able to recover and be completed.

Constructional Details

Technical details show that the concrete caissons were made in six different sizes to suit various depths of water. The largest size had a displacement of 6,044 tons, the smallest of 1,672 tons. When floating, the whole looked rather like a Noah's Ark without its roof, while, viewed from above, the cross walls made it look like an egg box, as there was no deck. At a late stage, Bofors guns, 20 tons of ammunition, and rough shelters for a gun's crew were placed on the top of most caissons as additional A.A. protection of the harbour. It took roughly 22 minutes to sink the largest-size caisson.

The numbers produced in the various sizes were 60 (largest), 11, 25, 23, 17 and 10 (smallest), a total of 146. Construction was in dry docks, wet docks, basins and slipways. The basins were holes excavated beside the Thames in which the lower layer of the caisson could be built as in a dry dock. A channel was then cut to the river and the caisson floated out to be completed in a wet dock berth. The wet dock berthing space required amounted to 12,000-ft. Construction sites were mainly in the Thames and Southampton areas.

The actual work was carried out by 25 large contracting firms. The total labour forces involved in the construction, which does not include the fabrication of many essential small parts, was about 20,000 men.

The piers consisted each of a single steel roadway carried on steel girders similar in many respects to an ordinary bridge, but so designed that there was such flexibility that the heaving and twisting effect of the sea could be withstood. Each of the bridge-spans was supported on special floats, some of steel and others on concrete, also designed to withstand the sea, and also to sit down on rock or sand when the tide receded. Sections of pier were joined together by special means to give flexibility and to ensure easy and rapid connecting up.

At the outer end the piers were linked to specially designed spud pierheads, consisting of steel pontoons with a displacement of approximately 1,000 tons. Coasters berth alongside and unload direct into lorries.

Pierheads were built, as ships, in various ports from Leith round to Glasgow. Most of the remaining equipment was prefabricated all over the country, and then assembled at the Army depots at Southampton and Richborough. Some 240 contractors were employed.

The floating breakwater consisted of steel floats, moored end-to-end in a long line. By March two rows were completed and moored under constant observation off the south coast. Units were prefabricated and then assembled at Southampton, where 2,000 men were employed. About 6,000 men were employed in other areas on prefabrication.

The fact that goods made of raw materials in short supply owing to war conditions are advertised in this Journal should not be taken as an indication that they are necessarily available for export.

Bluff Harbour Board, New Zealand

Excerpts from Chairman's Annual Address on Operations for Year ended 30th September, 1943

Income and Expenditure.—Summarised this account shows the following:—

	£
Income	33,731
Ordinary Expenditure	32,567
	1,164
Less Depreciation	7,407
Nett Loss being debit balance on the year's working	6,243

Last year the nett loss on the year's working was £5,876.

The surplus of Cash Assets over Loan Indebtedness and Cash Liabilities of the Board as at 30th September, 1943, was £9,701 as against £8,455 in 1942.

Until two years ago it was customary for the Chairman to give particulars of the trade of the Port and shipping handled for the twelve months, together with a comparison with other Ports in New Zealand, but in accordance with instructions from the Government this information is being withheld until after the war.

Harbour Improvements.—It was considered essential to keep the dredger going continuously and most of her time she was employed in deepening and cleaning the berths and dredging the swinging basin. The ebb tide carries along with it a slurry of sand which tends to silt up the swinging basin at the rate of about 1-in. per month, so it would appear that dredging will be necessary while we have heavy draught ships making Bluff a final port.

Channel widening has again been considered and the Board's Engineer was authorised to go into the question and report fully on the matter.

Obituary.—I regret to record the death of Mr. J. H. Reed who passed away on the 3rd August, 1943. Although a member of the Board for only two years, having been elected as one of the three representatives of the City of Invercargill and the Borough of South Invercargill on 5/5/1941, Mr. J. H. Reed proved himself an acquisition to this Board and to the many other concerns with which he was connected. He has left a great record of a worthy life served as a true New Zealander and he will be ever remembered as one of Southland's worthiest sons. He was specially gifted in ability, tact and speech, and it was always a pleasure to hear his discussions on any matter. His wise counsel will be greatly missed in future deliberations round the Board table.

Board Members.—It was with sincere regret that the Board received the resignation of Mr. Geo. A. Wraytt on account of continued ill-health on 25/8/1943, as he had served on the Board continuously since 26/5/1927 as one of the two representatives of the Southland County Council.

He rendered faithful and conscientious service to his constituents and his earlier training as a Marine Engineer made him peculiarly fitted to act as a member on such a body as a Harbour Board. His professional advice and sound judgment on matters with which he was intimate were greatly appreciated by his fellow-members on the Board, and he will be greatly missed in future discussions at the Board table. It is the sincere wish of the Chairman and Members of this Board that his health will improve and that he will be spared to enjoy his well-earned retirement from public life and local body affairs.

The vacancy on the board caused by the retirement of Mr. Wraytt, was filled by the Southland County Council's appointment of Mr. L. A. Niederer as their representative, in accordance with Section 38 (1) of the Harbours Act, the Southland County being a constituent district.

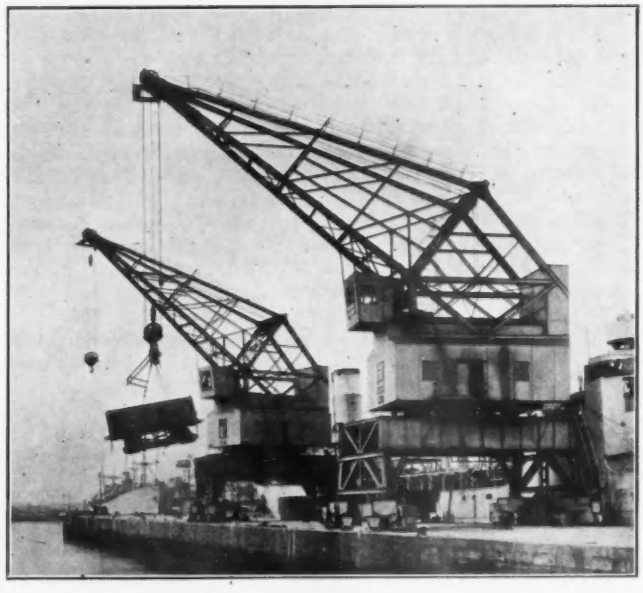
The vacancy caused by the death of Mr. J. H. Reed, one of the representatives of the combined district of the City of Invercargill and the Borough of South Invercargill, was filled by the appointment of his son, Mr. G. J. Reed, in accordance with Section 38 (2) of the Harbours Act under the hand of the Governor-General.

The above Report is signed by **W. J. A. McGregor,** Chairman, Bluff Harbour Board.

Coal Handling at the Port of Greenock

Installation of Electric Coaling Cranes

Two new electric coaling cranes, of 35 tons lifting capacity, built by Messrs. George Russell and Co., Ltd., of Motherwell, have recently been installed at the Port of Greenock. The following are the leading particulars of the cranes, which are shown in the accompanying illustration.



The maximum hook load is 35 tons; with cradle attached, coaling wagons up to 16 tons capacity can be lifted and tipped. There is a fixed radius of 60 feet. The power supply to the cranes is 440 volts, 3-phase, 50 cycles.

The jib-head pulleys are 87-ft. 6-in. above the rails on quay level. The carriage has 16 large travelling wheels, eight on each side. Travelling speed is 72-ft. per minute; Hoisting speed at full load: 56-ft. per minute; Lowering speed: 80-ft. per minute with field weakening; Tipping speed: 50-ft. per minute; Slewing speed: 450-ft. per minute.

The coaling cradle is of special design, and is completely automatic in action, with safety locking devices, which ensure that the axle gripping hooks are held in positive engagement so long as the cradle is lifted clear of the cradle seat.

The cranes were delivered to the specification of Mr. Donald Smith, M.Inst.C.E., General Manager and Engineer to the Greenock Harbour Trust.

Appointment of Port of London Representative in South Africa.

Recognising the necessity for restoring normal trade relationships as soon as possible, the Port of London Authority have appointed Colonel H. W. A. Webster, C.I.E., to be their representative in South Africa and Southern Rhodesia. Col. Webster has an extensive knowledge of the facilities and practices of the Port of London, having been in the service of the Authority since 1926. In 1939 he was commissioned in the Territorial Army Reserve of Officers with the rank of Major and was posted to the Intelligence Corps as Security Control Officer, Port of London. He relinquished his combined P.L.A. and Military duties in 1942 when he was appointed Security Liaison Officer in South Africa with the rank of Colonel.

Col. Webster officially took up his new duties for the Port of London on 1st October, having already made opportunities to visit most of the ports of South Africa and contacted many of the leaders of commerce in the country. He may be communicated with at " Etherston," Portland Road, Rondebosch, Cape Province.